Reduction of Healthcare Associated Infections through the use of Pulsed Xenon Ultraviolet Disinfection

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Reviewed by: Andrew Duong

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Healthcare associated infections (HAIs) are a global problem, causing hundreds of thousands of deaths each year, life-long disability to some survivors, and requiring billions of dollars of additional care. While the rate of device- and procedure-associated infections have shown improvement within United States acute care facilities, greater consideration should be given to other well-established sources of infection; such as the contaminated hospital environment [1].

The link between the environment and HAIs is best explained by what is known as the ‘prior room occupancy risk’ [2]. Patients admitted to rooms that were previously occupied by patients infected with common multidrug resistant organisms (MDROs) such as Clostridium difficile [3] (C. diff), Methicillin-resistant Staphylococcus aureus (MRSA) [4] and Vancomycin-resistant enterococci (VRE) [5] have been found to be at a 2.5, 1.5 and 2.25 times increased risk for developing the same infection, respectively [6]. Since there is no direct contact between the two patients, this risk of infection is almost exclusively associated with the environment. If not properly disinfected, these MDROs can linger on high touch surfaces for weeks to months, serving as a continued transmission risk for many future patients [7].

A growing number of healthcare organizations have turned to an innovative pulsed xenon ultraviolet (UV) light technology to complement standard cleaning protocols, with a goal to decrease HAIs. Pulsed xenon UV (PX-UV) disinfection (introduced to the healthcare market in 2010 by Xenex Disinfection Services) is the only UV disinfection technology shown to help hospitals effectively reduce their HAI rates and the body of evidence continues to mount [5-12]. Designed for speed, effectiveness and ease of use, hospital cleaning staff can operate the pulsed xenon Full Spectrum™ UV disinfection robot without disrupting the efficiency of hospital operations. The robot disinfects by releasing pulses of intense UV light spanning the full UV spectrum,
destroying viruses, bacteria and bacterial spores in a four-minute disinfection cycle. It has shown to be effective against contagious pathogens, including the Ebola virus and Anthrax spores (as tested in a BSL-4 laboratory at Texas BioMed, San Antonio, TX) [16]. Use of the robot has led to a reported ability to disinfect 30-62 hospital rooms per day; including patient rooms, operating rooms, equipment rooms, emergency rooms, intensive care units and communal areas.

In this article, we will review eight peer-reviewed studies demonstrating the clinical efficacy of the pulsed xenon UV disinfection system to reduce HAIs (Table 1). These outcomes identify important public health implications; estimating the number of infections avoided, as well as associated returns on investment and bed days generated as a result of the infection control interventions involved.

**Table 1. Summary of published HAI reduction studies associated with pulsed xenon ultraviolet disinfection systems**

<table>
<thead>
<tr>
<th>Study Site</th>
<th>Organism of Interest</th>
<th>Healthcare Setting</th>
<th>Incidence Reduction</th>
<th>Estimated Impact</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lowell General Hospital [8]</td>
<td>Class I Surgical site infections</td>
<td>Operating Room</td>
<td>46%</td>
<td>23 fewer cases in 10,883 procedures</td>
</tr>
<tr>
<td>Trinity Medical Center [9]</td>
<td>Total Hip/Knee SSIs (Class I)</td>
<td>Operating Room</td>
<td>100%</td>
<td>7 fewer cases in 544 procedures</td>
</tr>
<tr>
<td>Westchester Medical Center [10]</td>
<td>Multiple MDROs</td>
<td>Acute Care</td>
<td>20%</td>
<td>185 fewer cases in 22 months</td>
</tr>
<tr>
<td>Cooley Dickinson Hospital [11]</td>
<td><em>C. difficile</em></td>
<td>Acute Care</td>
<td>53%</td>
<td>17 fewer cases in 12 months</td>
</tr>
<tr>
<td>LTAC Facility [12]</td>
<td><em>C. difficile</em></td>
<td>LTAC</td>
<td>57%</td>
<td>29 fewer cases in 15 months</td>
</tr>
<tr>
<td>Westchester Medical Center [13]</td>
<td><em>C. difficile</em></td>
<td>ICU</td>
<td>70%</td>
<td>30 fewer cases in 12 months</td>
</tr>
<tr>
<td>Cone Healthcare System [14]</td>
<td><em>MRSA</em></td>
<td>Healthcare System</td>
<td>56%</td>
<td>58 fewer cases in 18 months</td>
</tr>
<tr>
<td>Orlando Health South Seminole Hospital [15]</td>
<td>Multiple MDROs; <em>C. difficile</em></td>
<td>Acute Care</td>
<td>61%</td>
<td>39 fewer cases in 22 months</td>
</tr>
</tbody>
</table>

Surgical Site Infections (SSIs) are devastating for patients and pose a significant financial risk for hospitals. Making up over 20 percent of all HAIs, SSIs are the leading type of infection within the U.S. [1]. Alabama-based Trinity Medical Center experienced a **100 percent decrease in class I surgical site infection rates** in its orthopedic operating rooms (ORs) after implementing a total joint infection control bundle that included quality improvements and pulsed xenon UV technology.
to disinfect its ORs and patient rooms [9]. The study states that the intervention may have prevented seven infections, averted one death, and saved $290,990 over the 12 months studied. In a similar fashion, an independent community hospital in the northeastern United States was able to achieve a 46 percent reduction in SSIs following class I (clean) surgical procedures [8]. Thorough terminal disinfection of 13 operating rooms was performed nightly in addition to standard between-case cleaning. The authors estimates the hospital avoided 23 infections and saved $487,055 as a result [8].

*C. diff* infection is a serious intestinal infection that can cause severe diarrhea, colitis and even death. Many hospital patients, especially those on antibiotics, are susceptible to *C. diff*. Recent publications funded by the Centers for Disease Control and Prevention (CDC) estimate that *C. diff* was responsible for over 12 percent of all HAIs within U.S. acute care facilities in 2011 [1]. When applied to all healthcare within the U.S., this organism was responsible for almost half a million infections and approximately 29,000 deaths [3]. Contaminated environments can be a source of *C. diff* infection, and thus, successful elimination of this associated transmission risk can have an overwhelming public health impact.

One study demonstrated that the use of pulsed xenon UV technology enabled Westchester Medical Center (New York, USA) to reduce hospital acquired *C. diff* infection rates in its adult intensive care unit (ICU) by 70 percent, potentially avoiding 30 cases over one year [13]. Previously, Westchester published a study reporting that the use of pulsed xenon ultraviolet light technology enabled the facility to reduce HAIs by 20 percent [7]. This decline in incidence occurred even though the hospital disinfected only 24 percent of targeted rooms. The before/after study discovered that the rate of HAIs caused by MDRO and *C. difficile* was significantly lower during the 22 months of pulsed xenon UV disinfection use compared with the 30-month period prior to implementation of pulsed xenon UV disinfection.

A 2013 study reported that Cooley Dickinson Hospital (an affiliate of Massachusetts General Hospital) experienced a 53 percent decrease in the rate of hospital-acquired *C. diff* infections after implementing the Xenex room disinfection system [11].

Another study published in 2013 reported on the pulsed xenon robot’s efficacy on MRSA infection rates. The hospital experienced a 56 percent reduction in its hospital acquired MRSA infection rate after implementing an infection prevention program that included the pulsed xenon room disinfection system [14]. Recently, Orlando Health South Seminole Hospital reported a 61 percent reduction in combined VRE, MRSA and *C. diff* infection rates in its Intensive Care Unit (ICU), an 87 percent reduction in its ICU VRE infection rate, and a 29 percent reduction facility-wide in combined VRE, MRSA and *C. diff* infection rates after it began using pulsed xenon light technology [15]. The hospital estimates that it saved $730,000 based on the number of *C. diff* and VRE infections that were avoided [15].

An interesting component of the Orlando Health study is its analysis of the efficacy of pulsed xenon
light in two different deployment strategies within the hospital. The difference in infection rate reduction was associated with two different utilization strategies, which provided an indicator for best practices for pulsed xenon disinfection. In the ICU, all discharges and transfers were disinfected with pulsed xenon UV, while non-ICU discharges were disinfected with pulsed xenon UV only under contact precautions for *C. diff*. As a result, the combined VRE, MRSA and *C.diff* infection rates decreased 61 percent in the ICU, whereas the non-ICU discharges and transfers resulted in only a 29 percent decrease in VRE, MRSA and *C.diff* infection rates facility wide.

Environmental contamination may pose a greater challenge in long-term care facilities than acute care settings because of the extended length of stay for patients and patient-to-patient contact. Patients inhabit rooms for weeks to months at a time, making thorough disinfection a challenge for environmental staff. Many hospitalized patients are transferred to and from Long Term Acute Care (LTAC) facilities, increasing the likelihood of acquiring a *C. diff* infection in the process. The use of pulsed xenon UV in communal living areas and patient rooms at an urban LTAC facility resulted in a 57 percent decrease in *C. diff* infection, and 29 fewer cases over a 15 month period [12].

**Conclusion:**

Standard cleaning practices have been shown to be inadequate in removing the dangerous pathogens from the environment that may infect the next patient in that room. Pulsed xenon UV disinfection provides healthcare facilities with a powerful tool to destroy potentially harmful microorganisms – enhancing the safety of patients and healthcare workers. Clinical effectiveness of this technology requires epidemiologically rooted implementation strategies and seamless integration into daily hospital operations, and cannot be overemphasized when considering the validity of UV technology.

**Disclosures:**

Dr. Mark Stibich is co-founder and Chief Scientific Officer of Xenex Disinfection Services. InfectionControl.tips received no funds and declares no conflict of interest in the publication of this article.

**References:**


Influence of pulsed-xenon ultraviolet light-based environmental disinfection on surgical site infections

Angela Catalanotti BSN, RN, Dudley Abbe BA, Sarah Simmons MPH, DrPH, Mark Stibich MHS, PhD

This study evaluates the influence of nightly pulsed-xenon ultraviolet light disinfection and dedicated housekeeping staff on surgical site infection (SSI) rates. SSIs in class I procedures were reduced by 46% (P = .0496), with a potential cost savings of $478,055. SSIs in class II procedures increased by 22.9%, but this was not significant (P = .6973). Based on these results, it appears that the intervention reduces SSI rates in clean (class I), but not clean-contaminated (class II) procedures.

Evidence exists that operating rooms (ORs) may remain contaminated after standard disinfection practices. Approximately 50% of surfaces are not adequately disinfected during between-case or terminal cleaning, and can harbor pathogenic organisms such as Pseudomonas spp, Acinetobacter spp, and Klebsiella spp. If these surfaces are not appropriately disinfected, the residual pathogens can cause the environmental surfaces to be a reservoir for pathogens. We sought to determine whether increased environmental disinfection in the OR would have an influence on surgical site infection (SSI) rates.

Recent advances in environmental disinfection have yielded “no touch” disinfection systems that use ultraviolet (UV) light to reduce residual microbial contamination in patient environments after manual cleaning. We investigated the use of pulsed-xenon UV (PX-UV) (Xenex Disinfection Services, San Antonio, TX). The PX-UV system uses intense, broad-spectrum pulses of germicidal UV to disinfect surfaces. The use of PX-UV disinfection has been reported to have reduced the hospital-acquired infection rates of Clostridium difficile, methicillin-resistant Staphylococcus aureus, and multidrug-resistant organisms within the acute care setting by 57%, 53%, and 20%, respectively. Recent international OR consensus guidelines suggest that the use of portable UV disinfection systems should be considered as an adjunct to traditional cleaning practices. New research has demonstrated that incorporating UV into a bundled approach to preventing SSIs has been effective in reducing orthopedic SSI rates.

The influence of UV disinfection on SSIs is likely to be correlated with the characteristics of the surgical case, primarily the prior contamination risk associated with the procedure. A measure for this contamination risk is the wound classification assigned postoperatively. Surgical wounds are divided into 4 classes: I = clean, II = clean-contaminated, III = contaminated, and IV = dirty-infected. The influence of UV disinfection would be expected to decrease as wound class increases, due to the pre-existing intrinsic contamination present during surgery. To control for the influence of wound class, the data were stratified in this study by wound class before analysis.

This study was conducted at an independent, not-for-profit community hospital in the northeastern United States that has more than 200 beds and 13 ORs. Institutional review board exemption was obtained. The analysis compares a baseline period that involved standard terminal cleaning and disinfection of the ORs to an intervention period during which an enhanced disinfection method using a PX-UV room disinfection system as well as dedicated personnel for terminal cleaning was implemented.

During the baseline period (January 2012-March 2013), OR staff performed thorough terminal disinfection of the ORs nightly as well as standard between-case cleaning. The OR staff received on-the-job training regarding appropriate techniques for disinfection of the...
ORs. Staff members were responsible for cleaning all surfaces and equipment within the OR.

During the intervention period (April 2013-December 2014), the between-case cleaning continued to be performed by the OR staff. However, the terminal cleaning process was performed by a dedicated housekeeper, and was augmented by the addition of PX-UV disinfection. After standard manual chemical clean, 2 PX-UV disinfection systems were placed in proximity to high-touch surfaces, such as the operating table, anesthesia machine, medication cart, and electrocautery control unit. All exposed surfaces in the OR received PX-UV disinfection. The room is not occupied while systems are operating. The 2 systems disinfected simultaneously for a 10-minute cycle. This is longer than the 5-minute cycle typically employed for PX-UV systems used in patient rooms due to the larger square footage of an OR. All ORs were given this treatment on a nightly basis. No PX-UV disinfection was performed between cases. No additional programs aimed at reducing SSIs were implemented during this intervention.

The sample included all class I and class II SSIs from January 2012 through December 2014. The preintervention sampling period was limited to 15 months due to changes in the surveillance definitions used for SSIs before January 2012. Trained infection preventionists tracked patients for signs and symptoms of SSI during their hospital stay and after discharge using the National Healthcare Safety Network definitions. Procedures were stratified by wound class into class I procedures or class II procedures. Class III and higher wound procedures are not included in the routine surveillance at the hospital. Wound class was documented by the surgeon after completion of the procedure. Infection rates were compared using a 1-sided Student t test.

### RESULTS

#### Class I procedures

Six thousand four hundred thirty-nine class I procedures were performed during the baseline period. Thirty-one SSIs occurred, for a rate of 0.48 per 100 cases. Ten thousand eight hundred eighty-three procedures were performed during the intervention period. Twenty-nine infections occurred, for a rate of 0.26 per 100 cases. This represents a 44.6% decrease in the infection rate \( (P = .0496) \), see Table 1. Based on the infection rate from the baseline period, a total of 52 class I SSIs would have been expected during the intervention period. Only 29 infections occurred, indicating that 23 potential infections were prevented. A timeline for class I infection rates is provided in Figure 1.

#### Class II procedures

Four thousand eight hundred eleven class II procedures were performed during the baseline period and 13 infections occurred, for an infection rate of 0.27 per 100 cases. In the intervention period, 7,825 procedures were performed and 26 infections occurred for an infection rate of 0.33 per 100 cases. This represents a 22.9% increase in infection rates. However, this change was not statistically significant \( (P = .6973) \) (see Table 1).

### DISCUSSION

The results show a significant reduction SSI rates for class I procedures during the intervention period. The success of the integration

<table>
<thead>
<tr>
<th>Type</th>
<th>SSIs</th>
<th>Procedures</th>
<th>Rate(^*)</th>
<th>SSIs</th>
<th>Procedures</th>
<th>Rate(^*)</th>
<th>% change</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Class 1</td>
<td>31</td>
<td>6,439</td>
<td>0.48</td>
<td>29</td>
<td>10,883</td>
<td>0.26</td>
<td>-44.6%</td>
<td>.0496</td>
</tr>
<tr>
<td>Class 2</td>
<td>13</td>
<td>4,811</td>
<td>0.26</td>
<td>26</td>
<td>7,825</td>
<td>0.33</td>
<td>+22.9%</td>
<td>.6973</td>
</tr>
</tbody>
</table>

\(^*\)Rate per 100 procedures.
of PX-UV systems and dedicated staff into cleaning and disinfection protocols demonstrates there is a likely link between surface disinfection and SSI rates for class I procedures. Using $20,785 as the average additional cost per infection,9 and a mortality rate of 3% for SSI,10 this intervention may have saved $478,055 and 1 life.

Infection rates for class II procedures did not change during the intervention period. The microbial load at the surgical site is greater for class II wounds, and it would be anticipated that the influence of environmental disinfection would be less meaningful than for procedures with a clean incision.

References

Brief report

Influence of a total joint infection control bundle on surgical site infection rates

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Key Words:
- Ultraviolet disinfection
- Role of environment in infection
- Total joint infections

Orthopedic surgical site infections (SSIs) from total knee or hip procedures are associated with a 3% rate of mortality\textsuperscript{1} and an additional cost of care of $20,785.\textsuperscript{2} Although Trinity Medical Center (www.trinitymedicalonline.com) SSI rates were already below the national average in 2012, facility leadership introduced the multiple interventions described below to reduce SSIs still further in 2013.

Trinity Medical Center is a 534-bed community health care provider that employs 200 professionals to serve Birmingham, Alabama, with inpatient, outpatient, diagnostic, surgical, and emergency services.

Best practices for perioperative care are well documented.\textsuperscript{1} Surface contamination in operating rooms can contaminate hands, instruments, and wounds, often through organisms becoming airborne during surgery.\textsuperscript{3-5} Studies show that pulsed xenon ultraviolet (PX-UV) light reduces microbial burden,\textsuperscript{6,7} so enhanced surface disinfection incorporating PX-UV was additionally deployed.

Quality improvement initiatives combined with pulsed xenon ultraviolet room disinfection were implemented to reduce surgical site infections (SSIs) in patients undergoing total joint procedures. After 12 months, knee SSIs were reduced from 4 to 0 ($P = .03$) and hip SSIs were reduced from 3 to 0 ($P = .15$) for a combined prevention of 7 SSIs ($P = .01$) and a savings of $290,990.

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Orthopedic surgical site infections (SSIs) from total knee or hip procedures are associated with a 3% rate of mortality\textsuperscript{1} and an additional cost of care of $20,785.\textsuperscript{2} Although Trinity Medical Center (www.trinitymedicalonline.com) SSI rates were already below the national average in 2012, facility leadership introduced the multiple interventions described below to reduce SSIs still further in 2013.

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Use of PX-UV is reported to have reduced hospital-acquired infection rates of Clostridium difficile, methicillin-resistant Staphylococcus aureus (MRSA), and multiple drug-resistant organisms within acute-care settings by 57%, 53%, and 20%, respectively.\textsuperscript{8-10} We report our experience of a change in SSI rates after combining PX-UV with quality improvement interventions.

METHODS

Two approaches were combined to reduce total joint SSIs: quality improvement and no-touch environment disinfection.

Quality improvement

The orthopedic wing was renovated and dedicated to total joint procedures only. Quality interventions were unified under a theme of promoting team spirit among both staff and patients. Stages of patient care were described as moving a ball into the end zone in football. Stages were preoperative classes, preoperative screening, and decolonization for MRSA/methicillin-sensitive S aureus,\textsuperscript{2} preoperative showers with chlorhexidine gluconate, skin cleansing with chlorhexidine gluconate immediately before surgery, standardized perioperative order sets, and early ambulation on the day of surgery when possible (Table 1). Stages were monitored and quantified when possible.

No-touch environment disinfection

Operating rooms were disinfected nightly using PX-UV. The PX-UV device (Xenex Healthcare Services, LLC, San Antonio, Tex) consists of a single bulb that produces a full spectrum (200-280 nm) ultraviolet C pulse from 505 J electrical energy.\textsuperscript{5} The device was operated for between 5 and 10 minutes in each of multiple positions selected to cover each operating room. Internal research demonstrated a 65.3% reduction in bacterial load after PX-UV disinfection compared with previous standard terminal cleaning. Upon discharge, patient rooms were also terminally cleaned and

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Conflicts of interest: None to report.

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http://dx.doi.org/10.1016/j.ajic.2015.09.010
RESULTS

Both components of the intervention were implemented fully by January 1, 2013. Patients before (2012) and after (2013) implementation did not differ in terms of age and MRSA score and seniority of nursing staff remained constant over the 2 years. Except for the interventions introduced, antibiotic treatment and wound dressings also remained constant. The average American Society of Anesthesiologists risk score for patients undergoing total-knee and total-hip procedures in 2012 and 2013 were 2.56 and 2.60, respectively.

Before full implementation, 4 SSIs were reported from 200 total-hip procedures (rate = 0.02) and 3 SSIs were reported from 191 total-knee procedures (rate = 0.0087) (Table 2); in sum, 7 infections from 544 procedures (rate = 0.0129). After full implementation, no SSIs were reported from either 191 total-hip procedures or 394 total-knee procedures (585 procedures). Using a rank sum test, Pvalues on these changes were .033 (hips), .149 (knees), and .015 (combined).

DISCUSSION

SSIs from total-hip and total-knee procedures were effectively eliminated following adoption of the combined interventions. Hence, a combination of renovation, consolidation of procedures, quality improvement, and no-touch disinfection seems to have made a substantial improvement in patient safety.

Using reported SSI costs5 and mortality1 data, this intervention may have prevented 14 infections, averted 1 death, and saved $290,990 over the 12 months studied. The practices introduced in 2013 have been continued to date with 1 infection occurring in 493 procedures in from January to June 2015 (rate = 0.002).

Although this was not a controlled clinical trial, retrospective investigation of hospital records for risk factors for SSIs other than those addressed by the interventions did not yield an obvious confounder. This study is unable to assess the influence on SSI rates of the individual components of the program. This was neither the design nor possible from the low number of events. Regardless, the overall cost of implementing the combined interventions was less than the estimated cost of the 7 SSIs that were prevented. Therefore, implementation of a similar combination of interventions and further investigations to maximize patient safety in total-joint procedures seems a logical recommendation.

References


Major article

Clostridium difficile infections before and during use of ultraviolet disinfection

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Key Words:
Ultraviolet disinfection
Hospital acquired
Clostridium difficile

Background: We previously reported a significant decrease in hospital-acquired (HA) Clostridium difficile infection (CDI) coincident with the introduction of pulsed xenon ultraviolet light for room disinfection (UVD). The purpose of this study was to evaluate CDI cases in greater detail to understand the effect of UVD.

Methods: CDI rates (HA and community acquired [CA]), CDI patient length of stay, room occupancy, and number of days between a CDI case in a room and an HA CDI case in the same room were studied for the first year of UVD compared with the 1-year period pre-UVD.

Results: Compared with pre-UVD, during UVD, HA CDI was 22% less (P = .06). There was a 70% decrease for the adult intensive care units (ICUs) (P < .001), where the percentage of room discharges with UVD was greater (P < .001). During UVD, CA CDI increased by 18%, and length of stay of all CDI cases was lower because of the greater proportion of CA CDI. No significant difference was found in days to HA CDI in rooms with a prior CDI occupant.

Conclusion: These data suggest that UVD contributed to a reduction in ICU-acquired CDI where UVD was used for a larger proportion of discharges. Evaluation of UVD should include data for hospitalized CA CDI cases because these cases may impact the HA CDI rate.

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Hospital-acquired Clostridium difficile infection (CDI) is a major cause of morbidity and mortality. CDI is considered to be a preventable infection, and hospital-specific CDI rates are now available to the public in several states, including New York. Environmental cleaning, hand hygiene, contact precautions, and close attention to antibiotic prescription are all considered essential measures to limit the acquisition of C difficile. The recovery of C difficile from the environment of rooms housing patients with C difficile ranges from 29% for asymptomatic carriers to 49%–100% for patients with CDI. Patients occupying rooms in which a prior occupant had CDI can be at significantly higher risk of acquiring CDI. C difficile spores can survive on hard surfaces for up to 5 months. Bleach can be used to kill the spore and is recommended to reduce the environmental reservoir of C difficile. However, regardless of the product used, studies examining discharge cleaning practices have shown that cleaning is often suboptimal; for example, in a multicenter study of 16 intensive care units (ICUs), on average only 57% of surfaces were cleaned effectively. In view of the importance of environmental contamination with C difficile, disinfection procedures that are not solely dependent on individual practice are being used. Machines that emit ultraviolet-C (UV-C) light can be used for room disinfection. UV-C light (200-320 nm) denatures DNA, halting the growth and reproduction of microorganisms. Ultraviolet light for room disinfection (UVD) machines cannot be used in occupied rooms. Two types of ultraviolet (UV) light machines are available for room disinfection: UV-C emitting devices, which provide continuous UV-C light from a mercury bulb in either a portable machine or a disinfecting wand, and pulsed xenon UV-C light. UVD has been shown to eradicate methicillin-resistant Staphylococcus aureus (MRSA), vancomycin-resistant enterococci (VRE), Acinetobacter, and C difficile under the
artificial conditions of inoculating surfaces with bacteria, exposing the bacteria to UV light and then culturing the surface. Studies have evaluated the impact of UVD in rooms that have housed patients by culturing surfaces before and after exposure to UVD. UVD was shown to significantly reduce positive *C difficile* and MRSA cultures from hospital rooms and was associated with halting the transmission of CDI between 2 roommates in a long-term care facility, whereas pulsed xenon UVD was associated with significant reductions in the microbial load of VRE in patient rooms. At our hospital, pulsed xenon UVD was added to standard cleaning of contact precautions rooms in May 2011. In a previously published study we observed a 17% reduction in hospital-acquired CDI coincident with the use of UVD for 22 months compared with a preintervention period of 30 months, which was statistically significant. The purpose of this study was to evaluate CDI during the first year of UVD in greater detail than was provided by the prior report, by including all CDI cases (hospital acquired and community acquired), evaluating length of stay and room occupancy, and assessing time from a CDI occupant in a room to a hospital-acquired CDI case occurring in the same room.

**METHODS**

This study compares a pre-UVD period (May 1, 2010-April 30, 2011) with the UVD period (July 1, 2011-June 30, 2012) for total CDI rates, hospital-acquired CDI rates, length of stay, and room occupancy. The months of May and June in 2011 were excluded because UV disinfection was not used consistently until late June 2011. This study was conducted at Westchester Medical Center, a tertiary care hospital located in Valhalla, New York. The hospital has 180 ICU beds and is a referral center for highly immunocompromised patients. All ICUs and pediatric rooms are single occupancy. On the adult service, 13% of the non-ICU rooms are single occupancy. The UVD procedures were standardized as follows. In each room, drawers, bed rails, phone, television remote, and blood pressure cuffs were placed in the path of UV light; the closets were also opened to be in the path of the UV light. Glass windows and door were covered with special curtains. In each room, doors were closed. In single-bed rooms, bathrooms were disinfected for 6 minutes. Then the machine was placed at the head and foot end of the bed for 12 minutes each. In semiprivate rooms, the bathrooms were cleaned first for 6 minutes. Then the UV machine was placed near the foot end of each bed for 6 minutes for a total of 12 minutes.

Contact precautions were required for all CDI cases until the patient had no diarrhea for a minimum of 3 consecutive days. Beginning in May 2011, UVD with pulsed xenon ultraviolet light (YANEX model; Xenex Healthcare Services, San Antonio, TX) was added after discharge cleaning for rooms housing contact precautions patients, as previously reported. Changes occurring during this study that could impact infection rates are as follows: on January 1, 2011 (4 months before UVD was implemented), a new environmental services company began providing services for the hospital; and in the spring of 2011 (just before UVD started), the pediatric oncology service was expanded to include more highly immunosuppressed patients.

For all CDI cases the following data were collected: length of stay before CDI, during contact precautions, and after discontinuation of contact precautions; rooms occupied throughout the hospital stay; and rates of new hospital-acquired and nonhospital-acquired CDI. During the UVD period the number of UVDs performed for CDI discharge and any discharge and the reason(s) for no UVD were tabulated. To assess how long rooms with a prior CDI occupant remained without a hospital-acquired CDI case during the 2 periods, rooms housing any CDI patient were followed from the day of room discharge cleaning until one of the following end points occurred: a hospital-acquired CDI case, the study period ended, or 5 months (150 days) had elapsed postdischarge cleaning. Days without a hospital-acquired CDI case in the room were compared for the 2 periods.

**Definitions**

CDI was defined as a patient with diarrhea and a positive stool test for *C difficile*. Hospital-acquired CDI was defined as a CDI case diagnosed at least 72 hours after admission that was not incubating at the time of admission and without a previously positive *C difficile* test during the prior 8 weeks. Community-acquired CDI was defined as all cases not acquired at Westchester Medical Center. Testing for CDI was performed using a polymerase chain reaction test for the toxin b gene (Cepheid GeneXpert System; Cepheid, Sunnyvale, CA). CDI cases were associated to specific units by infection prevention and control staff based on the patient’s location during the 48 hours prior to symptom onset. Incidence rates were the number of new CDI cases per 1,000 patient days. Days in a room were the number of days from the date of admission until the date of room discharge; for transfers within the hospital, the day of transfer was counted as a day in the new room. The number of UVD opportunities was the number of room discharges for patients on contact precautions for CDI.

**Statistics**

The sample size required for comparing the rates over the study time period was calculated based on an approach by Rosner. This computation requires an estimate of the effect size and an estimate of the average person-time contribution per patient. Based on a known rate of hospital-acquired CDI of 1.1 per 1,000 patient days per year at the Westchester Medical Center and a median length of stay of 11 days per patient, approximately 200,000 patient days per arm would provide 80% power to detect a 25% reduction in the rate of hospital-acquired CDI at a significance level of 5%. All data were entered into a standardized database. Median and interquartile ranges of lengths of stay were compared using the Wilcoxon rank-sum test. Categorical variables were compared using the Fisher exact test, and continuous variables were compared using the Student t test. Rates of CDI were compared by calculating incidence rate ratios with 95% confidence intervals. To compare time to hospital-acquired CDI cases in rooms previously housing a CDI patient, the median number of infection-free days in rooms during the preintervention and UVD period was compared using the Kaplan-Meier product–moment estimator and the log-rank test. Analyses were conducted in Stata (version 12.1; StataCorp, College Station, TX). The protocol was approved by the New York Medical College Committee for the Protection of Human Subjects.

**RESULTS**

There were 525 CDI cases (including both hospital-acquired and community-acquired cases) throughout the study: 251 cases occurred during the UVD period, and 274 cases occurred during the pre-UVD period. The total CDI rate (community acquired plus hospital acquired) was similar during the 2 periods (1.89 vs 1.96 CDI per 1,000 patient days; rate ratio [RR], 0.97; 95% confidence interval [CI], 0.81-1.15; P = .72). The rate of hospital-acquired CDI was 22% less during the UVD period, which was at borderline statistical significance (0.83 vs 1.06 CDI per 1,000 patient days; RR, 0.79; 95% CI, 0.61-1.00; P = .06) (Table 1, Fig 1). The rate of community-acquired CDI was 18% higher during the UVD period (1.06 vs 0.90 CDI per 1,000 patient days; RR, 1.18; 95% CI, 0.92-1.51; P = .20). The length of hospital stay for all CDI (hospital and community acquired) cases was significantly shorter during the UVD period.
median, 11; interquartile range, 6-24 days vs median, 15; interquartile range, 8-34 days; P < .01), likely related to the greater proportion of community-acquired cases during the UVD period (141/251 [56%] vs 126/274 [46%]; P = .02). When length of stay was compared for the hospital-acquired cases and for the community-acquired cases separately, length of stay for each group was unchanged between the 2 periods (Table 2).

A subanalysis of hospital-acquired CDI by service demonstrated a 70% reduction in the adult ICU population (P < .001). The overall rate for all services excluding the adult ICUs remained the same (0.89 vs 0.89 CDI per 1,000 patient days; RR, 1.00; 95% CI, 0.75-1.34; P = .10). Although the adult non-ICU rates decreased overall, the rate for the adult oncology unit increased, as did the rate for the pediatric units (Table 1). The increase in pediatric cases occurred almost entirely on the pediatric oncology unit. The increase in adult oncology cases was associated with recognized clusters of CDI cases on that unit.

CDI patients had 454 room discharges from 232 rooms in the pre-UVD period, and during the UVD period CDI patients had 359 room discharges from 183 rooms. The median infection-free days in the room after CDI patient discharge during the UVD and pre-UVD periods were similar (63 days; 95% CI, 31-77 days vs 60 days; 95% CI, 31-69 days; P = .79). When this was evaluated for only the ICU rooms, time to hospital-acquired CDI cases was longer, but not significantly longer (P = .43) (Fig 2). During the UVD period, 287 (80%) of the 359 CDI room discharges had UVD performed. The 72 missed opportunities were because patients were not moved to a

<table>
<thead>
<tr>
<th>Hospital acquired CDI cases</th>
<th>Preintervention period (n = 148)</th>
<th>Ultraviolet disinfection (n = 110)</th>
<th>Rate ratio 95% CI P value</th>
</tr>
</thead>
<tbody>
<tr>
<td>No. of cases</td>
<td>Patient days</td>
<td>Rate per 1,000 patient days</td>
<td>No. of cases</td>
</tr>
<tr>
<td>Total</td>
<td>148</td>
<td>139,677</td>
<td>1.06</td>
</tr>
<tr>
<td>Unit specific</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Adult non- ICU</td>
<td>68</td>
<td>76,075</td>
<td>0.89</td>
</tr>
<tr>
<td>Adult ICU</td>
<td>47</td>
<td>25,753</td>
<td>1.83</td>
</tr>
<tr>
<td>Adult oncology</td>
<td>16</td>
<td>13,871</td>
<td>1.15</td>
</tr>
<tr>
<td>Pediatrics</td>
<td>17</td>
<td>23,978</td>
<td>0.71</td>
</tr>
</tbody>
</table>

CDI, Clostridium difficile infection; CI, confidence interval; ICU, intensive care unit.

Fig 1. Cases of hospital-acquired Clostridium difficile infection before and during ultraviolet disinfection. In January 2011, a new environmental services company began service at the hospital. In August 2011 and May 2012, each month there were 5 cases of C difficile infection on the adult oncology unit resulting in audit of environmental services procedures on the unit. Abbreviation: UVC, ultraviolet-C.
The use of more sensitive diagnostic tests for CDI that were becoming available in settings both in hospitals and outside of hospitals. Data from New York State Department of Health indicate that the percentage of hospitals using the more sensitive tests has increased from 10% to 70% over the last 3 years.14

We studied length of stay of all CDI patients because all cases may contribute to CDI transmission. Length of stay of all CDI patients was significantly shorter during the UVD period because of the greater proportion of community-acquired CDI cases. These cases had a median length of stay of 2 weeks shorter than patients with hospital-acquired CDI (Table 2). The number of patient days with CDI as a proportion of all patient days on a unit is referred to as colonization pressure; colonization pressure has been shown to be an independent risk factor for acquiring CDI.15 Although we did not measure CDI contact precautions days, it is likely that the increase in community-acquired CDI cases during the UVD period partially offset the reduction in colonization pressure because of fewer hospital-acquired cases. The reduction in hospital-acquired CDI might have been even greater if the community-acquired cases had not increased.

In a previously published study from our hospital, Haas et al reported a significant 17% reduction in hospital-acquired CDI coincident with UVD use over a period of time that was approximately twice as long as this study.32 Although our study was not powered to detect statistically significant decreases in the 20%-25% range for CDI, the 22% reduction observed in the first year of UVD represents a clinically significant decrease. The 22% reduction (95% CI, 0.61-1.01) in hospital-acquired CDI was essentially caused by a highly significant 70% reduction (95% CI, 0.15-0.57) in the adult ICUs and a 20% reduction in the larger population of adult non-ICUs. The significant reduction in the adult ICUs may have been caused by the greater use of UVD in this location. The adult ICU rooms have significantly more UVDs performed per discharge because all ICU rooms are single bed and once UVD was available, the ICU staff began to request UVD regularly regardless of whether or not the discharged patient had been on contact precautions. Double-occupancy rooms outside of the ICU complicated UVD use, with roommates precluding use of UVD for approximately 20% of CDI discharges. Recent data suggest that only approximately one-third of hospital-acquired cases are caused by nosocomial transmission of similar strains and that many hospital-acquired cases may be caused by acquisition of a C difficile strain from other sources, such as asymptomatic carriers or their environments.38 This suggests that to interrupt transmission of C difficile there may need to be widespread use of UVD on a unit.

A prior room occupant with CDI has been shown to increase the risk of hospital-acquired CDI.14 In this study, during the UVD period we did not find a statistically significant increase in time to hospital-acquired CDI in rooms that previously housed CDI patients, even in the adult ICU rooms. The reasons for this may include the small sample size of adult ICU rooms, the total number of occupants and terminal cleansings between a CDI discharge and a hospital-acquired CDI case in the same room was not studied, and acquisition of C difficile may be dependent on the overall colonization pressure within a unit rather than the risk from the room alone.

The principal limitation of this study is the preintervention, intervention design, which cannot exclude confounding variables that affect CDI acquisition. The change to a new environmental services company 6 months before UVD started may have impacted CDI rates; however, both companies monitored cleaning similarly, and the decision to implement UVD was based on C difficile rates not decreasing during the first 3 months of use of the new environmental services company. We did not perform a randomized controlled study because our study was done soon after UVD was introduced and we needed to minimize errors in

### Table 2

<table>
<thead>
<tr>
<th></th>
<th>Preintervention period</th>
<th>UV disinfection period</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Length of stay</td>
<td></td>
<td></td>
</tr>
<tr>
<td>All CDI patients</td>
<td>Total days</td>
<td>15 (6-24)</td>
<td>.002</td>
</tr>
<tr>
<td>(n = 525)</td>
<td>Days before CDI</td>
<td>5 (1-13)</td>
<td>.039</td>
</tr>
<tr>
<td></td>
<td>Days on contact</td>
<td>7 (3-13)</td>
<td>.014</td>
</tr>
<tr>
<td></td>
<td>precondition</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Days post contact</td>
<td>0 (0-3)</td>
<td>.045</td>
</tr>
<tr>
<td></td>
<td>precondition</td>
<td>0 (0-0)</td>
<td>.10</td>
</tr>
<tr>
<td>Hospital-acquired</td>
<td>Total days</td>
<td>25 (13-48.5)</td>
<td>.11</td>
</tr>
<tr>
<td>CDI patients</td>
<td>Days before CDI</td>
<td>10 (6-19)</td>
<td>.75</td>
</tr>
<tr>
<td>(n = 258)</td>
<td>Days on contact</td>
<td>8 (4-15)</td>
<td>.15</td>
</tr>
<tr>
<td></td>
<td>precondition</td>
<td>0 (0-9)</td>
<td>.10</td>
</tr>
<tr>
<td></td>
<td></td>
<td>0 (0-1)</td>
<td>.47</td>
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<tr>
<td>Community-acquired</td>
<td>Total days</td>
<td>8 (5-16)</td>
<td>.15</td>
</tr>
<tr>
<td>CDI patients</td>
<td>Days before CDI</td>
<td>1 (0-3)</td>
<td>.65</td>
</tr>
<tr>
<td>(n = 267)</td>
<td>Days on contact</td>
<td>6.5 (3-10)</td>
<td>.12</td>
</tr>
<tr>
<td></td>
<td>precondition</td>
<td>0 (0-0)</td>
<td>.47</td>
</tr>
</tbody>
</table>

NOTE. Values are median (interquartile range) or as otherwise indicated. CDI, Clostridium difficile infection; UV, ultraviolet.

Fig 2. Days an intensive care room remained without a Clostridium difficile case after having housed a C difficile patient are shown for the 2 time periods and referred to as infection-free days. *P = .43. UV, ultraviolet.

### DISCUSSION

During the first year of UVD, the hospital-acquired CDI rate was 22% less than in the pre-UVD period. We were surprised to find that during this same time the community-acquired CDI rate increased by 18%, resulting in no overall decrease in total CDI cases. The increase in community-acquired cases documented during the UV disinfection period of this study may have been in part related to the use of more sensitive diagnostic tests for CDI that were

### Table 2

Length of stay for patients with CDI during the preintervention period and during the ultraviolet disinfection period

<table>
<thead>
<tr>
<th>CDI patients</th>
<th>Length of stay</th>
<th>Preintervention period</th>
<th>UV disinfection period</th>
<th>P value</th>
</tr>
</thead>
<tbody>
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<td></td>
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<tr>
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<td>3 (1-10)</td>
<td>.039</td>
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<tr>
<td></td>
<td>Days on contact</td>
<td>7 (3-13)</td>
<td>6 (3-10)</td>
<td>.014</td>
</tr>
<tr>
<td></td>
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<tr>
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<td>0 (0-3)</td>
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<td>.045</td>
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<tr>
<td></td>
<td>precondition</td>
<td>0 (0-0)</td>
<td>.10</td>
<td></td>
</tr>
<tr>
<td>Hospital-acquired</td>
<td>Total days</td>
<td>25 (13-48.5)</td>
<td>21 (11-35)</td>
<td>.11</td>
</tr>
<tr>
<td>CDI patients</td>
<td>Days before CDI</td>
<td>10 (6-19)</td>
<td>10 (7-17)</td>
<td>.75</td>
</tr>
<tr>
<td>(n = 258)</td>
<td>Days on contact</td>
<td>8 (4-15)</td>
<td>7 (3-12)</td>
<td>.15</td>
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<tr>
<td></td>
<td>precondition</td>
<td>0 (0-9)</td>
<td>0 (0-1)</td>
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<td>.15</td>
</tr>
<tr>
<td>CDI patients</td>
<td>Days before CDI</td>
<td>1 (0-3)</td>
<td>1 (0-2)</td>
<td>.65</td>
</tr>
<tr>
<td>(n = 267)</td>
<td>Days on contact</td>
<td>6.5 (3-10)</td>
<td>5 (2-9)</td>
<td>.12</td>
</tr>
<tr>
<td></td>
<td>precondition</td>
<td>0 (0-0)</td>
<td>0 (0-0)</td>
<td>.47</td>
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NOTE. Values are median (interquartile range) or as otherwise indicated. CDI, Clostridium difficile infection; UV, ultraviolet.

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During the first year of UVD, the hospital-acquired CDI rate was 22% less than in the pre-UVD period. We were surprised to find that during this same time the community-acquired CDI rate increased by 18%, resulting in no overall decrease in total CDI cases. The increase in community-acquired cases documented during the UV disinfection period of this study may have been in part related to the use of more sensitive diagnostic tests for CDI that were
use at the onset and to be sure that the procedures were accurately in place.

UV light disinfection can be performed using pulsed xenon UV light (used in this study) or continuous mercury bulb UV disinfection. Mercury bulbs emit a continuous low pressure light at a single range of 254 nm, and the effect of this UV light is cumulative requiring a longer cycle time of approximately 45 minutes for spore reduction. Pulse xenon UV disinfection emits a broad range of UV light from 200-280 nm in a high-intensity pulsatile manner, and the recommended average cycle time is approximately 18 minutes. Pulsed xenon devices also are somewhat safer because mercury-based devices can release toxic gases if they break accidentally.37 We choose to use the pulse xenon device because of the shorter cycle time. A recent study comparing the 2 devices in vitro, by inoculating organisms onto glass slides, found that mercury UV-C resulted in a significantly greater reduction of MRSA, VRE, and C difficile spores. However, in the same study, pulsed UV significantly reduced colony counts of MRSA, VRE, and C difficile spores in actual hospital rooms in which frequently touched surfaces were cultured before and after UVD.38 Although this reduction was less than that attained by continuous mercury UV-C, it may be sufficient given the low inoculum of bacteria on environmental surfaces.38 The study also demonstrated that the effectiveness of pulsed UV light is reduced when distance between the UV light and surfaces is 1.22 m. In our study we standardized positioning of the pulsed UV light, but some surfaces in the room would have been >1.22 m away. A randomized comparison of the continuous mercury UV-C versus pulsed UV-C light in a hospital setting is needed to further understand the differences between these devices.

Overall, these data suggest that UVD contributes to a reduction in ICU-acquired CDI and may be an important adjunct to standard cleaning practices. The reduction in CDIs is likely related to the greater use of UVD in the ICU, where rooms have single beds and patient movement is tightly controlled. After 1 year of UVD, hospital-acquired CDI rates were 22% lower despite an 18% increase in patient movement is tightly controlled. After 1 year of UVD, greater use of UVD in the ICU, where rooms have single beds and cleaning practices. The reduction in CDIs is likely related to the standardized positioning of the pulsed UV light, but some surfaces in the room would have been >1.22 m away. A randomized comparison of the continuous mercury UV-C versus pulsed UV-C light in a hospital setting is needed to further understand the differences between these devices.

Use of high-touch surfaces in isolation rooms to reduce contamination of healthcare workers’ hands. Infect Control Hosp Epidemiol 2012;33:1039-42.


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Brief report

The effect of portable pulsed xenon ultraviolet light after terminal cleaning on hospital-associated *Clostridium difficile* infection in a community hospital

Joanne Levin MD, FSHEA,*, Linda S. Riley RN, MEd, CIC,a Christine Parrish MSc, MSN, RN, CIC,a Daniel English MHCIMA,b Sehoon Ahn BS,c

a Department of Infection Prevention, Cooley Dickinson Hospital, Northampton, MA
b Department of Environmental Services, Cooley Dickinson Hospital, Northampton, MA
c Department of Quality, Cooley Dickinson Hospital, Northampton, MA

There is evidence that contamination of patient rooms from previous occupants is associated with hospital-associated *Clostridium difficile* infection (HA-CDI). During January 2011, the use of 2 portable pulsed xenon ultraviolet light devices (PPX-UV) to disinfect patient rooms was added to routine hospital discharge cleaning in a community hospital. In 2010, the HA-CDI rate was 9.46 per 10,000 patient-days; in 2011, the HA-CDI rates was 4.45 per 10,000 patient-days (53% reduction, \(P = .01\)). The number of deaths and colectomies attributable to hospital-associated *C. difficile* infection also declined dramatically.

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METHODS

Cooley Dickinson Hospital is a 140-bed acute care community hospital in western Massachusetts with mostly single-bed rooms. During January 2011, the use of 2 PPX-UV devices (Xenex Healthcare Services, San Antonio, TX) to disinfect patient rooms was introduced. Rooms and bathrooms were terminally cleaned as usual with a hospital-grade disinfectant product (ph7Q Ultra; Betco Corporation, Toledo, OH) in most rooms and a chlorine-based product (Clorox Clean-up and Clorox Germ Wipes; The Clorox Company, Oakland, CA) in *C difficile* rooms. This was followed by the use of PPX-UV, for three 7-minute exposures (once in the bathroom and then in 2 locations in the main patient room). The overall room turn-over time was extended by approximately 15 minutes over a standard terminal cleaning because cleaning could continue in the main room during PPX-UV treatment of the bathroom.

PPX-UV devices were also used in the operating suites (nights), emergency department (early mornings), and other clinical areas as available. Surveillance for HA-CDI (hospital onset plus community onset) using SHEA definitions continued as per Infection

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E-mail address: joanne_levin@cooley-dickinson.org (J. Levin).
Conflicts of interest: None to report.
Prevention Department routine. No environmental sampling was performed.

Description and cost of the device

The PPX-UV device contains a xenon flash lamp that emits a broad spectrum of light covering the germicidal, or ultraviolet-C (UV-C), spectrum of 200 to 280 nm as well as the visible light spectrum. The device weighs approximately 150 pounds and is approximately 20 inches wide by 30 inches long by 38 inches high. The PPX-UV system produces a pulsed flash at a frequency of 1.5 Hz with an approximate output of 505 J per pulse and a duration of less than 360 μs. The device is operated remotely by ES personnel in the hallway just outside the patient room and includes safety features such as motion sensors, which turn off the device if the door is opened. The operating time for the device for C difficile deactivation was 7 minutes per position. Leasing 2 machines cost less than $5,000 per month.

Baseline infection prevention policies and ES procedures

Throughout the study period, our policy followed SHEA guidelines including use of chlorine-based agents for terminal cleaning of C difficile rooms, use of soap and water for hand hygiene, and contact precautions for the duration of the hospital stay. Patients were put on contact precautions when C difficile infection was suspected but not necessarily proven. Adherence to policy was not measured. No new infection prevention policies or protocols were pursued during the intervention year.

There was no real-time antibiotic stewardship before or during the intervention. However, ciprofloxacin was added to the formulary in early 2010, with a decline in levofloxacin use and total quinolone use. As noted in Table 1, levofloxacin use (adjusted for patient-days) declined 38.6% with a rise in ciprofloxacin use, and total quinolone use declined 14.8% during the year prior to the intervention. During the intervention year, levofloxacin use continued to fall, although more modestly, and total quinolone use fell minimally. No new formulary initiatives were pursued during the intervention year.

In the previous 2 years, ES workers were educated to standardize cleaning practices and were taught about the role of environmental contamination in transmitting infections. In addition, an improved communication system (using beeper messages to alert ES staff when a room needed to be cleaned) was implemented to increase efficiency in room turnover and to inform housekeepers when chlorine-based products were needed.

PPX-UV implementation

The PPX-UV device utilization was prioritized as follows: discharged contact precaution rooms, intensive care unit rooms, and other medical/surgical/labor and delivery rooms (with the goal of using the PPX-UV device in every room after patient discharge), and in operating rooms, emergency department rooms, and on shared medical equipment when possible. No new ES workers were hired to implement this protocol.

Testing for and diagnosing C difficile

In early 2009 in-house testing for C difficile was changed from a toxin A-only enzyme immunoassay card test to the Meridian Immunocard Toxins A and B (Meridian, Charlotte, NC), with occasional use of a send-out polymerase chain reaction (PCR) test (Real-time PCR using LightCycler and Fluorescent Resonance Energy Transfer; Mayo, Rochester, MN). In 2011 results from (more frequently used) PCR tests were also included in the data. The definition we used for HA-CDI did not change over the study periods. Genotyping was not performed.

Statistical analysis

HA-CDI rates were compared using a 1-tailed test calculated using Stata Data Analysis and Statistical Software (STATA Corp, College Station, TX).

RESULTS

HA-CDI rates

The HA-CDI rate per 10,000 patient-days was reduced from 9.46 in 2010 to 4.45 in 2011 (53% reduction; P = .01; 95% confidence interval: 6.40-12.4; t = 2.491). Previously rates were stable at an average of 9.22 for the years 2008 to 2010 (compared with 2011, 52% reduction; P = .002; 95% confidence interval: 7.58-10.8; t = 2.97). It should be noted that, of the 15 patients who were diagnosed with HA-CDI in 2011, 11 (73%) were placed in rooms that had not been treated with the PPX-UV device prior to occupation. Overall, 56% of discharged rooms received the UV light treatment. One reason some rooms were not treated was the simultaneous discharge of a number of patients and the limited number of devices. In addition, whereas most of our rooms are single occupancy, occasionally 2-bed rooms with 1 patient remaining could not be fully treated, although often the bathroom was treated. The at-risk population at our facility had a fairly stable median age (57.5-58.4 years), and our patient acuity index rose slightly (see Table 2).

Death and colectomy

During 2011, there was 1 attributable death, and there were no attributable colectomies, whereas there were 6 and 3, respectively, in 2010; 8 and 1, respectively, in 2009; and 4 and 1, respectively, in 2008.

DISCUSSION

The HA-CDI rate in 2011, during the use of PPX-UV, was significantly lower than during the previous 1 year and than the average of the previous 3 years. The inclusion of PCR data in 2011 would have increased our rate of positive tests, if all other factors were the
same, thus making a change in data collection or testing unlikely to have accounted for our results. Hospital average age and acuity index increased slightly between 2010 and 2011, which probably would have increased patient risk for HA-CDI (see Table 2).

Because antibiotic use—in particular levofloxacin—may be a risk factor for the development of HA-CDI, our quinolone usage was evaluated (see Table 1). Total quinolone use fell prior to the implementation of PPX-UV but remained relatively stable between the 1 year prior and the intervention year. Interestingly, levofloxacin use declined significantly during the previous 1 year (2010) without a major change in HA-CDI compared with the prior year (2009). Levofloxacin use continued to decline modestly in the study year, with a rise in ciprofloxacin use compared with the previous year. Given that a dramatic decline in levofloxacin use did not appear to affect the HA-CDI rate between 2009 and 2010, it appears unlikely that further changes in quinolone use accounted for the significant change in HA-CDI during the study year.

The total number of HA-CDI-related deaths and colectomies decreased substantially, with no colectomies attributable to HA-CDI occurring during the intervention year. Additionally, the rate of death because of HA-CDI declined. This may be attributable to the decrease in number of cases and/or to the severity of cases.

Whereas the goal was to use PPX-UV in every room at terminal cleaning, discharges often occurred simultaneously. With only 2 devices, and patients waiting to be admitted, some rooms were not treated. However, vacated precaution rooms were given priority for treatment with PPX-UV. In addition, there are approximately 30 rooms that may have double occupancy when the census is high. Because people should not be exposed to the PPX-UV light, 2-bed rooms vacated by 1 patient but housing the second could not be treated, although in those situations ES staff often used the device in the bathroom only.

Prior to implementation of PPX-UV, ES workers were trained in the use of the device as well as the important role the workers play in preventing illness and death. Although adding PPX-UV to their routine did increase their workload, as a group they felt great pride in being a part of the infection prevention team and playing an enhanced role in patient care. Although there were some initial issues with bulb longevity, the use of PPX-UV was quickly and easily integrated into the ES work schedule without additional staff.

The quasiexperimental design of this study makes definitive declaration of cause and effect impossible. Besides a continued decrease in the use of levofloxacin and an increase in ciprofloxacin use, no other significant antibiotic usage or infection prevention policy changes were known to occur. In addition, whereas the total number of subjects under surveillance was large, the total number of subjects with HA-CDI was small. The study does reflect, however, the successful implementation of this new technology in a real-world setting, with improved patient outcomes.

The dramatic reduction in infection, death, and colectomy due to HA-CDI after PPX-UV was added to standard infection prevention interventions makes this technique well worth investigating further in a large center with well-controlled variables.

### References


### Table 2

<table>
<thead>
<tr>
<th>Year</th>
<th>2008</th>
<th>2009</th>
<th>2010</th>
<th>2011</th>
</tr>
</thead>
<tbody>
<tr>
<td>Patients</td>
<td>12</td>
<td>16</td>
<td>18</td>
<td>20</td>
</tr>
<tr>
<td>Deaths</td>
<td>4</td>
<td>8</td>
<td>6</td>
<td>1</td>
</tr>
<tr>
<td>Colectomies</td>
<td>1</td>
<td>3</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>Rate of death for HA-CDI</td>
<td>8.36</td>
<td>9.85</td>
<td>9.46</td>
<td>4.45</td>
</tr>
<tr>
<td>Rate of colectomy for HA-CDI</td>
<td>0.13</td>
<td>0.22</td>
<td>0.18</td>
<td>0.067</td>
</tr>
<tr>
<td>Number of community-associated CDI (inpatient and outpatient)</td>
<td>0.03</td>
<td>0.03</td>
<td>0.09</td>
<td>0.00</td>
</tr>
<tr>
<td>Percentage of discharge rooms treated with PPX-UV</td>
<td>46</td>
<td>66</td>
<td>62</td>
<td>58</td>
</tr>
<tr>
<td>Number of discharge rooms treated with PPX-UV</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>56</td>
</tr>
<tr>
<td>Number (%) of HA-CDI patients whose rooms were not treated with PPX-UV prior to admission</td>
<td>32 (100)</td>
<td>36 (100)</td>
<td>33 (100)</td>
<td>11 (73)</td>
</tr>
<tr>
<td>Hospital patient-days</td>
<td>38,263</td>
<td>36,540</td>
<td>34,870</td>
<td>33,687</td>
</tr>
<tr>
<td>Hospital average age</td>
<td>57.9</td>
<td>58.4</td>
<td>57.5</td>
<td>58.3</td>
</tr>
<tr>
<td>Hospital acuity index (Diagnosis-related group case weight, Centers for Medicare and Medicaid Services)</td>
<td>0.0953</td>
<td>1.1265</td>
<td>1.1315</td>
<td>1.1386</td>
</tr>
</tbody>
</table>

*Comparison of HA-CDI rate in 2010 vs 2011: 53% reduction, *P* < .01; 95% confidence interval: 6.40-12.4; *t* = 2.481. The average HA-CDI rate for 2008-2010 was 9.22. Comparison of this rate with 2011 rate: 52% reduction; *P* = .002; 95% confidence interval: 7.58-10.8; *t* = 2.97.*
The emergence and prevalence of dangerous “superbugs,” such as Clostridium difficile (C. diff), methicillin-resistant Staphylococcus aureus (MRSA), and other multidrug-resistant organisms (MDROs), in health care settings has called for heightened infection prevention and control efforts in all aspects of patient care. In particular, greater attention has been given to the role of the environment in the transmission of deadly pathogens and the incidence of health care-acquired infections (HAIs). Evidence shows that contaminated hospital surfaces play a key role in the transmission of C. diff and that enhanced environmental cleaning is needed for rooms that house C. diff patients. As health care facilities look to improve their environmental cleaning, “no-touch” methods for room disinfection are emerging as viable options that can augment traditional room cleaning processes.

Pulsed UV technology
The pulsed xenon ultraviolet (UV) light disinfection system from Xenex Disinfection Services uses high-intensity pulses to emit UV light at frequencies that cross the germicidal UV range, the range at which microorganisms are susceptible to UV damage. The high UV frequencies offer different pathways of damage to microorganisms by damaging cell walls and cellular structures and impeding the ability for microorganisms to replicate. “The intensity of the pulse gives it a couple other properties, so it reflects very differently around the room than conventional mercury UV and does different types of damage to organisms, but it’s also easier on the equipment in the room as well,” said Mark Stibich, PhD, MHS, BA, chief scientific officer for Xenex. “It penetrates the cell wall of spores, viruses, and bacteria, so anything with DNA or RNA is susceptible.”

Considered a green technology, the pulsed UV system uses xenon, a naturally occurring noble gas that is viewed as environmentally friendly. The device can be used across multiple areas in a health care facility, including patient rooms, ORs, equipment rooms, emergency rooms (ERs), intensive care units, shared staff member areas, and public areas. The most common usage is for ORs, either for in between cases or augmenting the end of the day cleaning. One device can serve multiple ORs and be on call for use between cases, and is especially beneficial for cleaning an
OR after a “dirty” case (e.g., a patient with an MDRO). Health care facilities can get 24-hour use of the device, which can disinfect more than 30 rooms per day.

Comparable in size and mobility to a wheelchair, the disinfection robot is wheeled into a room and the user unlocks the device with an ID and password on a keypad. Once the button is pushed to activate the device, the device waits 15 seconds for the user to exit the room, then motion sensors scan the room for 15 seconds before beginning to pulse the UV light. On average, each OR requires the device to be used in two positions for 5-10 minutes in each position. During this time, the device logs data of the room in use, when the device is used, and the dosage.

**Adoption of the pulsed UV system**

Individuals from Rose Medical Center, a private hospital in Denver, Colo. wanted to eliminate *C. diff* and all hospital-acquired MDROs from their facility, so they looked to technology to assist with providing the safest patient environment possible. “We are an organization where zero hospital-acquired infections is the only acceptable outcome for our patients,” said Michelle Bauer, director of environmental services at Rose Medical Center. “We looked at best practices across the country and this looked like one of the best opportunities for us to address any potential residual *C. diff* in any patient room or type of isolation room.”

After looking at many technologies, including a disinfection system that used mercury to generate UV light and a hydrogen peroxide misting tool, Rose representatives chose the pulsed UV system primarily for its speed and ease of use. “It really answered all our questions as far as ‘Is it easy to use? Is it safe for the environment? Is it going in the direction of the environmental concerns for our world at this point?’ and ‘Is it going to help us achieve our zero infection rate goals?’” said Bauer. During a six-week trial period with the robot in January 2012, Rose experienced zero reports of *C. diff* or HAIs in the facility. The robot also helped Rose deal with a recent outbreak of norovirus in Colorado that had affected many staff members and was occurring at the same time as the trial. After using the robot to disinfect the shared staff member areas (e.g., nurses’ station), Rose staff members stopped calling in sick from the norovirus, which they attributed to the UV disinfection device.

After purchasing the device, Rose staff members spent a week in training with vendors. End users were trained on how to use the device, and nurses, physicians, and managers attended meetings to learn how to maximize its use across the facility. The training involved as many clinical staff members as possible to get buy-in to the process and make staff members feel comfortable using the robot. Stibich said that robots are often named during the orientation process, and some even receive their own employee ID badges. “Facilities kind of adopt the robot as part of the team and it’s a neat phenomenon,” said Stibich. “Environmental services staff members especially take a lot of pride in the robot and it helps with being acknowledged that they’re part of the continuum of care for patients.”

**Usage and results**

On average, the robot is used to disinfect 15 rooms a day at Rose. Facility members strategize use of the device based on their top priority rooms, which are the isolation rooms, critical care rooms, ORs, and procedural rooms, and then dispatch the device to other discharge rooms as needed. Users also run the device daily in the ER and clean all of their surgical suites on a weekly basis. “Most of our rooms take about 15 minutes to run the unit properly through the room, and for a terminal clean of a *C. diff* room, it saves us about 45 minutes time,” said Katie Sawicki, infection control specialist at Rose Medical Center. Infection prevention team members also provide unit-by-unit infection rates, and when rates decline or reach zero, they will send notes to...
environmental services staff members to let them know they’re saving lives. Staff members also leave table tents in every patient room cleaned with the device to notify patients that their room has been disinfected using UV light to make the environment safer for them.

Since Rose implemented the technology, staff members have been able to reduce the use of bleach in their facility’s cleaning processes and have kept their C. diff rates at zero. The only challenge they reported is competition for time with the device. Their goal is to be able to clean 28 rooms a day with the robot. “We feel like the benefit of it [the system] is that if we can be at zero C. diff and HAIs, we will have saved tons of money and impacted personal lives,” said Sawicki. “If anyone is questioning whether or not to do something like this with this technology, it’s more about the value of your patient’s experience as far as C. diff or MRSA and where are you at with managing that.”

**Conclusion**
As more attention is given to the role of the environment in HAI risk, the use of “no-touch” technologies, like the pulsed xenon UV system, may become part of standard room disinfection practices as more research studies validate the benefits of such technologies. “The innovative hospitals that are really interested in making a change and working closely with all their teams, such as the infection control team and the environmental team, they’re the ones asking the question ‘What more can we do?’” said Stibich.

Rose Medical Center’s experience demonstrated that a health care facility does not need high infection rates to get a measurable return on investment from using pulsed UV disinfection technology. The disinfection method has helped the facility become more environmentally friendly through the reduced use of bleach, garnered positive staff member and patient feedback, and contributed to a safe environment for patients and staff members and significant cost savings by keeping C. diff and MDROs at bay. “Here at Rose, we really do feel that the Xenex technology is a commitment to our patient safety,” said Sawicki.

**References**
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First UK trial of Xenex PX-UV, an automated ultraviolet room decontamination device in a clinical haematology and bone marrow transplantation unit [star]

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b Department of Clinical Microbiology, Nottingham University Hospitals NHS Trust, Nottingham, UK

[star] Data from this study were presented at the Infection Prevention Society conference, Glasgow, UK, September 29th to October 1st, 2014 (Presentation No. 2968).

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SUMMARY

Background: There is growing interest in the use of no-touch automated room decontamination devices within healthcare settings. Xenex PX-UV is an automated room disinfection device using pulsed ultraviolet (UV) C radiation with a short cycle time.

Aim: To investigate the microbiological efficacy of this device when deployed for terminal decontamination of isolation rooms within a clinical haematology unit.

Methods: The device was deployed in isolation rooms in a clinical haematology unit. Contact plates were applied to common touch points to determine aerobic total colony counts (TCCs) and samples collected using Polywipe™ sponges for detection of vancomycin-resistant enterococci (VRE).

Results: The device was easy to transport, easy to use, and it disinfected rooms rapidly. There was a 76% reduction in the TCCs following manual cleaning, with an additional 14% reduction following UV disinfection, resulting in an overall reduction of 90% in TCCs. There was a 38% reduction in the number of sites where VRE was detected, from 26 of 80 sites following manual cleaning to 16 of 80 sites with additional UV disinfection.

Conclusions: The Xenex PX-UV device can offer a simple and rapid additional decontamination step for terminal disinfection of patient rooms. However, the microbiological efficacy against VRE was somewhat limited.

Keywords:
Xenex
Ultraviolet (UV) Decontamination

Introduction

Healthcare-associated infections (HCAIs) remain a significant source of morbidity and mortality for patients despite a number of national infection prevention and control initiatives.\(^1\) These have included guidance on hand hygiene as well as standards on cleanliness within a healthcare environment.\(^1\) Hand hygiene is especially important at reducing the cross-transmission of pathogens, and further improvements can be achieved through reducing the bioburden at touch points.\(^1\) However, several studies have shown that manual cleaning is often suboptimal, and improvements through education and feedback are difficult to maintain.\(^2\)\(^-\)\(^4\)

In order to reduce the risks of operator error during cleaning, there is growing interest in no-touch automated room decontamination devices such as hydrogen peroxide and ultraviolet (UV) radiation.\(^5\)\(^,\)\(^6\) UV radiation has been shown to be efficacious at killing a number of bacteria including spore-forming organisms through destruction of nucleic acids.\(^7\) A number of these devices are now available on the market and studies have demonstrated efficacy in seeded plate and simulated experiments against meticillin-resistant *Staphylococcus aureus* (MRSA), multi-resistant acinetobacter (MRA) and vancomycin-resistant enterococci (VRE).\(^8\)\(^-\)\(^10\) VRE remain important nosocomial pathogens, and infection is associated with increased morbidity, particularly in haematology patients undergoing bone marrow transplantation.\(^11\)

This study investigated the efficacy of the PX-UV device (Xenex disinfection services) as a means of (i) reducing the total aerobic colony counts (TCCs) on surfaces and (ii) removing environmental reservoirs of VRE in an isolation room on a busy haematology and bone marrow transplant unit.

Methods

Clinical setting

This study was performed in single occupancy, isolation, en-suite rooms in clinical haematology wards in a large teaching hospital. Rooms were sampled immediately after the discharge of a patient. The clinical haematology unit performs weekly surveillance stool cultures on inpatients for carriage of VRE. Eight of the 18 rooms in this study were sampled following occupancy by confirmed VRE-positive patients.

PX-UV device use and disinfection

The Xenex PX-UV machine measured 48×40×100 cm in size, with a movable section containing a xenon gas flash bulb. The flash bulb pulsed a broad spectrum of UV light, which is bactericidal.\(^12\) The device contained a number of safety mechanisms to assist and protect
the user, including warning signs and a motion sensor to automatically cease operation if movement is detected. Within each room, the device was deployed at three locations, each for a 5 min disinfection cycle, to ensure that all sites directly received at least once cycle of UV disinfection in the line of sight (Figure 1). On average, 25 min were required to perform the room disinfection.

Environmental samples

Environmental sampling was performed in 10 rooms at three time-points: (1) immediately following patient discharge, (2) following a manual clean performed by cleaning services staff using a general purpose detergent in warm water as per national standards, and (3) immediately after completion of three PX-UV disinfection cycles. In each room, 10 standard sampling points were identified that included areas at risk of direct faecal contamination, which included a variety of touch points (e.g. bed controls, chair arm, patient table) and areas that may be difficult to access for cleaning (e.g. floor in corner) (Table I). TCCs were assessed using Tryptone Soya Agar contact plates (E&O Laboratories, Bonnybridge, UK). The plates were incubated at 37°C for 48 h and the total colony-forming units (cfu) enumerated.

In another eight rooms, 10 sampling points were swabbed with a Polywipe™ sponge (Medical Wire and Equipment, Corsham, UK) at time-point (2), following a manual clean using a general purpose detergent in warm water as per national standards, and at time-point (3), immediately after PX-UV surface disinfection. In each of the sampling sites, adjacent areas were selected at each time-point to mitigate against the effects of additional cleaning through sampling. The sponges were immersed in 30 mL of brain–heart infusion broth (Oxoid, Basingstoke, UK) and incubated at 37°C for 12–18 h. Ten microlitres of the broth were subcultured on to VRE-selective agar (Oxoid) which was incubated at 37°C for 48 h. Blue or purple colonies indicating probable VRE were confirmed using Gram staining, Bile-aesculin positivity and vancomycin sensitivity testing. VRE sampling was performed in different rooms and at separate time-points from TCCs.

Data analysis

Quantitative data (TCCs) were summarized using box–whisker plots and a chi-squared test was performed to compare the percentage of VRE-positive samples before and after PX-UV disinfection. \( P < 0.05 \) was considered statistically significant.

Results

Total aerobic colony counts

Overall, a median of 35.5 cfu per contact plate [interquartile range (IQR): 17.25–111.5] was detected prior to cleaning from a total of 100 sampling points. This was
reduced to a median of 4 cfu per contact plate (IQR: 1–4) following manual cleaning and to 2 cfu/contact plate (IQR: 0–4) following deployment of PX-UV (Figure 2). Following UV decontamination, floor areas in front of the toilet in two separate rooms remained heavily contaminated despite being in an easily accessible location to clean manually and in the direct line of UV exposure (Table II).

**VRE detection**

In all, 160 Polywipe sponge samples were obtained from eight patient rooms. VRE was detected from 26/80 (32.5%) samples post cleaning and from 16/80 (20%) samples post Xenex PX-UV (P = 0.072, chi-squared test) (Table III). There appeared to be no poorly performing sampling sites from which VRE was consistently detected, because the positive results were spread across all the 10 sites in the eight different rooms.

**Discussion**

This small study of the Xenex PX-UV device has demonstrated effectiveness at reducing the overall bioburden at critical touch-points in the clinical environment. The device also showed an additional reduction in the detection of VRE following manual cleaning, but this was not statistically significant.

There are several limitations to this study. It was performed in one institution and sampling was performed in a small number of rooms. A limited number of touch-points were sampled in the rooms and this may not accurately reflect the true level of contamination. Ideally the sampling should have been performed in triplicate, at each location in each room, to achieve a mean value. We did not assess efficacy of Xenex PX-UV against *Clostridium difficile* and MRSA because the incidence of these two organisms in our haematology and bone marrow transplant unit is currently very low.

The main advantages of this device were that it was easy to use and had rapid cycle times for disinfection, which meant that there was improved uptake from the cleaning services team. However, the short cycle times may have reduced efficacy against key pathogens. In addition, Xenex PX-UV does not contain mercury bulbs, unlike some continuous UV decontamination devices, hence there are no safety hazards associated with mercury disposal.

Sampling of touch points using contact plates showed a large reduction in bacterial bioburden following manual cleaning (76%) and a further reduction (14%) in TCCs following UV disinfection. The highest TCCs were recovered from floors in the room and toilet, as well as the toilet bin lid.

Following manual cleaning, VRE was cultured from a number of sites and UV disinfection led to small a reduction in the number of locations where VRE remained detectable. Our methodology was optimized for maximum sensitivity for VRE detection using
broth enrichment, hence it was not possible to quantify the degree of environmental VRE contamination in terms of cfu. From our results, we conclude that the three 5 min cycles of UV disinfection do not ensure total eradication of VRE. However, longer periods of UV emission might increase the effectiveness of this device against VRE.

A recent study using seeded surfaces in a simulated environment has shown that short-pulsed UV devices are somewhat less effective than continuous UV radiation.12

In summary, pulsed UV is an emerging decontamination technology that is effective at reducing bacterial contamination in the clinical environment to some degree, but further studies are required to elucidate whether this technology should be relied upon for terminal disinfection of rooms of patients with VRE and other important HCAI pathogens.

Acknowledgements

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Conflict of interest statement
None declared.

Funding sources
None.

References


**Author query**

Please check url for Ref. 13.
Table I

Sites sampled using contact plates for total colony counts (A–J) and using Polywipe™ sponges for vancomycin-resistant enterococci (1–10)

<table>
<thead>
<tr>
<th>Number</th>
<th>Sampling sites</th>
</tr>
</thead>
<tbody>
<tr>
<td>A/1</td>
<td>Top of patient table</td>
</tr>
<tr>
<td>B/2</td>
<td>Floor in corner of the room</td>
</tr>
<tr>
<td>C/3</td>
<td>Bed controls</td>
</tr>
<tr>
<td>D/4</td>
<td>Floor in front of toilet</td>
</tr>
<tr>
<td>E/5</td>
<td>Top of service rail</td>
</tr>
<tr>
<td>6</td>
<td>Nurse call buzzer</td>
</tr>
<tr>
<td>7</td>
<td>Door handle – bathroom</td>
</tr>
<tr>
<td>8</td>
<td>Bed safety rail</td>
</tr>
<tr>
<td>9</td>
<td>Tap on sink</td>
</tr>
<tr>
<td>10</td>
<td>Toilet flush handle</td>
</tr>
<tr>
<td>F</td>
<td>Top of fridge</td>
</tr>
<tr>
<td>G</td>
<td>Toilet bin lid</td>
</tr>
<tr>
<td>H</td>
<td>Chair arm (left)</td>
</tr>
<tr>
<td>I</td>
<td>Chair arm (right)</td>
</tr>
<tr>
<td>J</td>
<td>Telephone on top of locker</td>
</tr>
</tbody>
</table>
Table II

Total aerobic colony counts from the 10 sampled sites in 10 rooms before cleaning, after manual cleaning, and after ultraviolet disinfection

<table>
<thead>
<tr>
<th>Site</th>
<th>Before cleaning</th>
<th>After manual cleaning</th>
<th>After ultraviolet disinfection</th>
</tr>
</thead>
<tbody>
<tr>
<td>Top of patient table</td>
<td>17 (0–39)</td>
<td>2 (0–5)</td>
<td>0 (0–2)</td>
</tr>
<tr>
<td>Floor in corner of the room</td>
<td>132 (29–278)</td>
<td>5 (0–171)</td>
<td>2 (1–54)</td>
</tr>
<tr>
<td>Bed controls</td>
<td>19 (2–148)</td>
<td>2 (0–23)</td>
<td>1 (0–7)</td>
</tr>
<tr>
<td>Floor in front of toilet</td>
<td>56 (1–220)</td>
<td>3 (0–121)</td>
<td>2 (0–167)</td>
</tr>
<tr>
<td>Top of service rail</td>
<td>62 (6–136)</td>
<td>3 (0–37)</td>
<td>2 (0–12)</td>
</tr>
<tr>
<td>Top of fridge</td>
<td>35 (3–131)</td>
<td>3 (0–92)</td>
<td>1 (0–18)</td>
</tr>
<tr>
<td>Toilet bin lid</td>
<td>103 (10–259)</td>
<td>32 (2–171)</td>
<td>1 (0–32)</td>
</tr>
<tr>
<td>Chair arm (left)</td>
<td>22 (7–333)</td>
<td>12 (0–126)</td>
<td>4 (0–27)</td>
</tr>
<tr>
<td>Chair arm (right)</td>
<td>23 (5–267)</td>
<td>10 (0–102)</td>
<td>2 (0–5)</td>
</tr>
<tr>
<td>Telephone on top of locker</td>
<td>34 (15–187)</td>
<td>13 (0–26)</td>
<td>1 (0–18)</td>
</tr>
</tbody>
</table>

Values are median (range).
Table III

Number of vancomycin-resistant enterococci (VRE)-positive sites\(^a\) after manual cleaning and additional ultraviolet (UV) disinfection

<table>
<thead>
<tr>
<th>Area</th>
<th>No. of VRE-positive sites after manual cleaning</th>
<th>No. of VRE-positive sites after additional UV disinfection</th>
</tr>
</thead>
<tbody>
<tr>
<td>Room 1</td>
<td>3/10</td>
<td>1/10</td>
</tr>
<tr>
<td>Room 2</td>
<td>6/10</td>
<td>4/10</td>
</tr>
<tr>
<td>Room 3</td>
<td>0/10</td>
<td>0/10</td>
</tr>
<tr>
<td>Room 4</td>
<td>2/10</td>
<td>1/10</td>
</tr>
<tr>
<td>Room 5</td>
<td>2/10</td>
<td>1/10</td>
</tr>
<tr>
<td>Room 6</td>
<td>4/10</td>
<td>4/10</td>
</tr>
<tr>
<td>Room 7</td>
<td>8/10</td>
<td>5/10</td>
</tr>
<tr>
<td>Room 8</td>
<td>1/10</td>
<td>0/10</td>
</tr>
<tr>
<td>Total</td>
<td>26/80</td>
<td>16/80</td>
</tr>
</tbody>
</table>

\(^a\)VRE was detected using broth enrichment, hence quantification of bacterial load at sampling sites was not possible.
Figure 1. Three positions of deployment of the Xenex PX-UV device, for 5 min at each location.
Figure 2. Box-plot demonstrating total aerobic colony counts from contact plates before cleaning, after manual cleaning, and after ultraviolet disinfection.
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A. Beal et al.

First UK trial of Xenex PX-UV, an automated ultraviolet room decontamination device in a clinical haematology and bone marrow transplantation unit[star]

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[star]Data from this study were presented at the Infection Prevention Society conference, Glasgow, UK, September 29th to October 1st, 2014 (Presentation No. 2968).

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SUMMARY

Background: There is growing interest in the use of no-touch automated room decontamination devices within healthcare settings. Xenex PX-UV is an automated room disinfection device using pulsed ultraviolet (UV) C radiation with a short cycle time.

Aim: To investigate the microbiological efficacy of this device when deployed for terminal decontamination of isolation rooms within a clinical haematology unit.

Methods: The device was deployed in isolation rooms in a clinical haematology unit. Contact plates were applied to common touch points to determine aerobic total colony counts (TCCs) and samples collected using Polywipe\textsuperscript{TM} sponges for detection of vancomycin-resistant enterococci (VRE).

Results: The device was easy to transport, easy to use, and it disinfected rooms rapidly. There was a 76% reduction in the TCCs following manual cleaning, with an additional 14% reduction following UV disinfection, resulting in an overall reduction of 90% in TCCs. There was a 38% reduction in the number of sites where VRE was detected, from 26 of 80 sites following manual cleaning to 16 of 80 sites with additional UV disinfection.

Conclusions: The Xenex PX-UV device can offer a simple and rapid additional decontamination step for terminal disinfection of patient rooms. However, the microbiological efficacy against VRE was somewhat limited.

Keywords: Xenex
Ultraviolet (UV) Decontamination

Introduction

Healthcare-associated infections (HCAIs) remain a significant source of morbidity and mortality for patients despite a number of national infection prevention and control initiatives. These have included guidance on hand hygiene as well as standards on cleanliness within a healthcare environment. Hand hygiene is especially important at reducing the cross-transmission of pathogens, and further improvements can be achieved through reducing the bioburden at touch points. However, several studies have shown that manual cleaning is often suboptimal, and improvements through education and feedback are difficult to maintain.

In order to reduce the risks of operator error during cleaning, there is growing interest in no-touch automated room decontamination devices such as hydrogen peroxide and ultraviolet (UV) radiation. UV radiation has been shown to be efficacious at killing a number of bacteria including spore-forming organisms through destruction of nucleic acids. A number of these devices are now available on the market and studies have demonstrated efficacy in seeded plate and simulated experiments against meticillin-resistant Staphylococcus aureus (MRSA), multi-resistant acinetobacter (MRA) and vancomycin-resistant enterococci (VRE). VRE remain important nosocomial pathogens, and infection is associated with increased morbidity, particularly in haematology patients undergoing bone marrow transplantation.

This study investigated the efficacy of the PX-UV device (Xenex disinfection services) as a means of (i) reducing the total aerobic colony counts (TCCs) on surfaces and (ii) removing environmental reservoirs of VRE in an isolation room on a busy haematology and bone marrow transplant unit.

Methods

Clinical setting

This study was performed in single occupancy, isolation, en-suite rooms in clinical haematology wards in a large teaching hospital. Rooms were sampled immediately after the discharge of a patient. The clinical haematology unit performs weekly surveillance stool cultures on inpatients for carriage of VRE. Eight of the 18 rooms in this study were sampled following occupancy by confirmed VRE-positive patients.

PX-UV device use and disinfection

The Xenex PX-UV machine measured 48×40×100 cm in size, with a movable section containing a xenon gas flash bulb. The flash bulb pulsed a broad spectrum of UV light, which is bactericidal. The device contained a number of safety mechanisms to assist and protect
the user, including warning signs and a motion sensor to automatically cease operation if
movement is detected. Within each room, the device was deployed at three locations, each for
a 5 min disinfection cycle, to ensure that all sites directly received at least once cycle of UV
disinfection in the line of sight (Figure 1). On average, 25 min were required to perform the
room disinfection.

Environmental samples

Environmental sampling was performed in 10 rooms at three time-points: (1) immediately following patient discharge, (2) following a manual clean performed by cleaning
services staff using a general purpose detergent in warm water as per national standards, and
(3) immediately after completion of three PX-UV disinfection cycles. In each room, 10
standard sampling points were identified that included areas at risk of direct faecal
contamination, which included a variety of touch points (e.g. bed controls, chair arm, patient
table) and areas that may be difficult to access for cleaning (e.g. floor in corner) (Table I).
TCCs were assessed using Tryptone Soya Agar contact plates (E&O Laboratories,
Bonnybridge, UK). The plates were incubated at 37°C for 48 h and the total colony-forming
units (cfu) enumerated.

In another eight rooms, 10 sampling points were swabbed with a Polywipe™ sponge
(Medical Wire and Equipment, Corsham, UK) at time-point (2), following a manual clean
using a general purpose detergent in warm water as per national standards, and at time-point
(3), immediately after PX-UV surface disinfection. In each of the sampling sites, adjacent
areas were selected at each time-point to mitigate against the effects of additional cleaning
through sampling. The sponges were immersed in 30 mL of brain–heart infusion broth
(Oxoid, Basingstoke, UK) and incubated at 37°C for 12–18 h. Ten microlitres of the broth
were subcultured on to VRE-selective agar (Oxoid) which was incubated at 37°C for 48 h.
Blue or purple colonies indicating probable VRE were confirmed using Gram staining, Bile-
aesculin positivity and vancomycin sensitivity testing. VRE sampling was performed in
different rooms and at separate time-points from TCCs.

Data analysis

Quantitative data (TCCs) were summarized using box–whisker plots and a chi-squared
test was performed to compare the percentage of VRE-positive samples before and after PX-
UV disinfection. \( P < 0.05 \) was considered statistically significant.

Results

Total aerobic colony counts

Overall, a median of 35.5 cfu per contact plate [interquartile range (IQR):
17.25–111.5] was detected prior to cleaning from a total of 100 sampling points. This was
reduced to a median of 4 cfu per contact plate (IQR: 1–4) following manual cleaning and to 2 cfu/contact plate (IQR: 0–4) following deployment of PX-UV (Figure 2). Following UV decontamination, floor areas in front of the toilet in two separate rooms remained heavily contaminated despite being in an easily accessible location to clean manually and in the direct line of UV exposure (Table II).

VRE detection

In all, 160 Polywipe sponge samples were obtained from eight patient rooms. VRE was detected from 26/80 (32.5%) samples post cleaning and from 16/80 (20%) samples post Xenex PX-UV ($P = 0.072$, chi-squared test) (Table III). There appeared to be no poorly performing sampling sites from which VRE was consistently detected, because the positive results were spread across all the 10 sites in the eight different rooms.

Discussion

This small study of the Xenex PX-UV device has demonstrated effectiveness at reducing the overall bioburden at critical touch-points in the clinical environment. The device also showed an additional reduction in the detection of VRE following manual cleaning, but this was not statistically significant.

There are several limitations to this study. It was performed in one institution and sampling was performed in a small number of rooms. A limited number of touch-points were sampled in the rooms and this may not accurately reflect the true level of contamination. Ideally the sampling should have been performed in triplicate, at each location in each room, to achieve a mean value. We did not assess efficacy of Xenex PX-UV against Clostridium difficile and MRSA because the incidence of these two organisms in our haematology and bone marrow transplant unit is currently very low.

The main advantages of this device were that it was easy to use and had rapid cycle times for disinfection, which meant that there was improved uptake from the cleaning services team. However, the short cycle times may have reduced efficacy against key pathogens. In addition, Xenex PX-UV does not contain mercury bulbs, unlike some continuous UV decontamination devices, hence there are no safety hazards associated with mercury disposal.

Sampling of touch points using contact plates showed a large reduction in bacterial bioburden following manual cleaning (76%) and a further reduction (14%) in TCCs following UV disinfection. The highest TCCs were recovered from floors in the room and toilet, as well as the toilet bin lid.

Following manual cleaning, VRE was cultured from a number of sites and UV disinfection led to small a reduction in the number of locations where VRE remained detectable. Our methodology was optimized for maximum sensitivity for VRE detection using
broth enrichment, hence it was not possible to quantify the degree of environmental VRE contamination in terms of cfu. From our results, we conclude that the three 5 min cycles of UV disinfection do not ensure total eradication of VRE. However, longer periods of UV emission might increase the effectiveness of this device against VRE.

A recent study using seeded surfaces in a simulated environment has shown that short-pulsed UV devices are somewhat less effective than continuous UV radiation.¹²

In summary, pulsed UV is an emerging decontamination technology that is effective at reducing bacterial contamination in the clinical environment to some degree, but further studies are required to elucidate whether this technology should be relied upon for terminal disinfection of rooms of patients with VRE and other important HCAI pathogens.

Acknowledgements

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Conflict of interest statement

None declared.

Funding sources

None.

References


**Author query**

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Table I

Sites sampled using contact plates for total colony counts (A–J) and using Polywipe™ sponges for vancomycin-resistant enterococci (1–10)

<table>
<thead>
<tr>
<th>Number</th>
<th>Sampling sites</th>
</tr>
</thead>
<tbody>
<tr>
<td>A/1</td>
<td>Top of patient table</td>
</tr>
<tr>
<td>B/2</td>
<td>Floor in corner of the room</td>
</tr>
<tr>
<td>C/3</td>
<td>Bed controls</td>
</tr>
<tr>
<td>D/4</td>
<td>Floor in front of toilet</td>
</tr>
<tr>
<td>E/5</td>
<td>Top of service rail</td>
</tr>
<tr>
<td>6</td>
<td>Nurse call buzzer</td>
</tr>
<tr>
<td>7</td>
<td>Door handle – bathroom</td>
</tr>
<tr>
<td>8</td>
<td>Bed safety rail</td>
</tr>
<tr>
<td>9</td>
<td>Tap on sink</td>
</tr>
<tr>
<td>10</td>
<td>Toilet flush handle</td>
</tr>
<tr>
<td>F</td>
<td>Top of fridge</td>
</tr>
<tr>
<td>G</td>
<td>Toilet bin lid</td>
</tr>
<tr>
<td>H</td>
<td>Chair arm (left)</td>
</tr>
<tr>
<td>I</td>
<td>Chair arm (right)</td>
</tr>
<tr>
<td>J</td>
<td>Telephone on top of locker</td>
</tr>
</tbody>
</table>
Table II

Total aerobic colony counts from the 10 sampled sites in 10 rooms before cleaning, after manual cleaning, and after ultraviolet disinfection

<table>
<thead>
<tr>
<th>Site</th>
<th>Before cleaning</th>
<th>After manual cleaning</th>
<th>After ultraviolet disinfection</th>
</tr>
</thead>
<tbody>
<tr>
<td>Top of patient table</td>
<td>17 (0–39)</td>
<td>2 (0–5)</td>
<td>0 (0–2)</td>
</tr>
<tr>
<td>Floor in corner of the room</td>
<td>132 (29–278)</td>
<td>5 (0–171)</td>
<td>2 (1–54)</td>
</tr>
<tr>
<td>Bed controls</td>
<td>19 (2–148)</td>
<td>2 (0–23)</td>
<td>1 (0–7)</td>
</tr>
<tr>
<td>Floor in front of toilet</td>
<td>56 (1–220)</td>
<td>3 (0–121)</td>
<td>2 (0–167)</td>
</tr>
<tr>
<td>Top of service rail</td>
<td>62 (6–136)</td>
<td>3 (0–37)</td>
<td>2 (0–12)</td>
</tr>
<tr>
<td>Top of fridge</td>
<td>35 (3–131)</td>
<td>3 (0–92)</td>
<td>1 (0–18)</td>
</tr>
<tr>
<td>Toilet bin lid</td>
<td>103 (10–259)</td>
<td>32 (2–171)</td>
<td>1 (0–32)</td>
</tr>
<tr>
<td>Chair arm (left)</td>
<td>22 (7–333)</td>
<td>12 (0–126)</td>
<td>4 (0–27)</td>
</tr>
<tr>
<td>Chair arm (right)</td>
<td>23 (5–267)</td>
<td>10 (0–102)</td>
<td>2 (0–5)</td>
</tr>
<tr>
<td>Telephone on top of locker</td>
<td>34 (15–187)</td>
<td>13 (0–26)</td>
<td>1 (0–18)</td>
</tr>
</tbody>
</table>

Values are median (range).
Table III

Number of vancomycin-resistant enterococci (VRE)-positive sites\textsuperscript{a} after manual cleaning and additional ultraviolet (UV) disinfection

<table>
<thead>
<tr>
<th>Area</th>
<th>No. of VRE-positive sites after manual cleaning</th>
<th>No. of VRE-positive sites after additional UV disinfection</th>
</tr>
</thead>
<tbody>
<tr>
<td>Room 1</td>
<td>3/10</td>
<td>1/10</td>
</tr>
<tr>
<td>Room 2</td>
<td>6/10</td>
<td>4/10</td>
</tr>
<tr>
<td>Room 3</td>
<td>0/10</td>
<td>0/10</td>
</tr>
<tr>
<td>Room 4</td>
<td>2/10</td>
<td>1/10</td>
</tr>
<tr>
<td>Room 5</td>
<td>2/10</td>
<td>1/10</td>
</tr>
<tr>
<td>Room 6</td>
<td>4/10</td>
<td>4/10</td>
</tr>
<tr>
<td>Room 7</td>
<td>8/10</td>
<td>5/10</td>
</tr>
<tr>
<td>Room 8</td>
<td>1/10</td>
<td>0/10</td>
</tr>
<tr>
<td>Total</td>
<td>26/80</td>
<td>16/80</td>
</tr>
</tbody>
</table>

\textsuperscript{a}VRE was detected using broth enrichment, hence quantification of bacterial load at sampling sites was not possible.
Figure 1. Three positions of deployment of the Xenex PX-UV device, for 5 min at each location.
Figure 2. Box-plot demonstrating total aerobic colony counts from contact plates before cleaning, after manual cleaning, and after ultraviolet disinfection.
How pulsed xenon UV disinfection kills the pathogens in the hospital environment that cause dangerous and costly infections

SUMMARY

Healthcare associated infections (HAIs) remain a serious and potentially lethal problem for patients and a significant source of unreimbursed expense for hospitals. High-touch surfaces in patient environments are well-established sources of infections, but traditional cleaning regimens fail to eliminate many pathogens.

A growing number of healthcare organizations are turning to new technologies to complement standard cleaning protocols. Most of these technologies have been shown to kill microorganisms in the laboratory setting. It is known that these tests do not reflect the real-world environment. When evaluating these technologies, it is essential to review the studies published in the scientific literature that give evidence of the technology’s ability to reduce actual rates of HAIs.

Pulsed xenon ultraviolet light disinfection, introduced to the healthcare market in 2010 by Xenex Disinfection Services, is the only environmental disinfection technology with reported HAI rate reductions in multiple peer reviewed research articles. The Xenex system kills a broad range of pathogenic microorganisms, including hardy C. diff spores, on high-touch surfaces within 10 to 15 minutes per room. Hospital environmental service staff are easily trained to use the Xenex robot.

This paper discusses the peer reviewed research that has evaluated the effectiveness of the Xenex technology and the financial benefits associated with the adoption of this technology.
THE PROBLEM

Despite signs of recent progress, healthcare associated infections (HAIs) remain the largest source of preventable harm to patients. A recent survey by the Centers for Disease Control and Prevention (CDC) found that 1 in 25 hospital patients had at least one HAI and 75,000 hospital patients die from them each year. Other estimates are far higher, making HAIs one of the leading causes of death in the U.S.

The CDC reported in March 2014 that some infections reported to its National Healthcare Safety Network had fallen significantly from 2008 to 2012, but there had been minimal decreases for both hospital-onset Clostridium difficile infections (CDI) and hospital-onset methicillin-resistant Staphylococcus aureus (MRSA) bloodstream infections, both associated with contaminated patient environments. C. difficile, a virulent form of diarrhea, is linked to 14,000 American deaths each year. It is the most common HAI, causing 12% of all healthcare associated infections, while MRSA is second at 10.7%. Those and other infections not related to the use of medical devices or surgeries account for 52.6% of all HAIs.

HAIs are an incredible economic burden on the US healthcare system. They cause longer lengths of stay and more intensive care, accounting for $40 billion in excess costs in 2009, according to the CDC. The average total cost for a single inpatient CDI is more than $35,000. An array of public and private sector payment initiatives makes high rates of HAIs a significant detriment to the bottom line of hospitals and other healthcare facilities. One analysis found that a hospital with $50 million in annual Medicare inpatient revenue might have as much as $6.6 million at risk as a result of high infection rates.

Beazley, a leading insurer of hospital professional liability risks that maintains a claims database covering 39% of U.S. hospital beds, estimates that the average cost of all successful medical malpractice claims rose 2% in 2013 to $492,000. One recent case cited by Beazley involved a New York hospital, which paid $179 million to a patient who underwent quadruple amputation as a result of a virulent infection acquired in the hospital.

An infection can also become a serious public relations problem, causing harm to the hospital’s reputation as a safe place to seek care. Lawsuits are reported in the local news and in online reviews for hospitals. Infection rates are publicly reported on the Centers for Medicare and Medicaid Services’ (CMS) Hospital Compare website, and the Leapfrog Group includes infections in its calculation of the Hospital Safety Score, which garners widespread media attention.

Conversely, visible action to improve room cleanliness is a significant contributor to higher patient satisfaction, a key component of performance under the Hospital Inpatient Value-Based Purchasing Program.

THE HOSPITAL ENVIRONMENT AND INFECTIONS

The role of the healthcare environment in the transmission of infections is becoming clearer. Serious pathogens, such as MRSA, C. difficile and vancomycin-resistant Enterococcus (VRE), have been isolated from the environment. Environmental sources have been linked to multiple outbreaks of infections due to these pathogens.

Almost everything that comes into contact with a patient eventually becomes contaminated with bacteria, which makes it easy for the bacteria to transfer between surfaces and people.

Traditional cleaning regimens using bleach or quaternary ammonium compounds reduce room contamination but fail to eliminate many pathogens. These compounds require long dwell times on hard surfaces, time that most staffs don’t have. And those compounds are not recommended for soft surfaces, which might get no more than a dusting, even in a terminal cleaning.

There is significant variability in cleaning procedures between hospitals and among staff within the hospital. A comparative study at Central Texas Veterans Health Care System in Temple, Texas, found that consistency in patient room cleaning was lacking. “High residual colony counts were observed on the toilet seats post-cleaning ... this may be due to human inconsistency or memory failure regarding which parts of the room have been cleaned, a common problem with repetitive tasks,” the authors found.

Hospital rooms are full of equipment, which makes it even easier to acquire infections from the environment. Devices, screens, monitors and tubes can all harbor bacteria, but cleaning staff are not always permitted to touch this equipment, and it may not be known exactly whose duty it is to clean it. Many devices are becoming increasingly complex and difficult to clean, even for experienced clinicians.
Worse, amid tightening budgets, environmental services departments are often targeted for cost savings. According to Patti Costello, executive director of the Association for the Healthcare Environment, “ES teams are under pressure to turn rooms more quickly and care for the environment with fewer resources. There doesn’t seem to be widespread acknowledgement of the data that support the environment as key to improved satisfaction scores and outcomes with respect to reducing infection rates.”

TECHNOLOGICAL SOLUTIONS

A growing number of healthcare organizations are turning to technologies that complement standard cleaning programs. While some of these technologies have laboratory data concerning their ability to kill organisms, most of the solutions do not have published data on the impact on both HAI rates and hospital operations.

For example, one study found that the use of hydrogen peroxide vapor (HPV) disinfection was associated with an overall reduction in multi-drug resistant organisms (MDROs) of 64%, although the patients’ reduced risk of acquiring CDI, MRSA and gram-negative bacterial infections could not be solely attributed to HPV.

Ultraviolet light has been used for air and water disinfection for decades. There are now dozens of companies marketing mercury bulb UV light devices for surface disinfection in healthcare facilities. Mercury bulbs contain elemental mercury, which is a toxic substance. Special handling is necessary if a mercury bulb breaks, and special disposal requirements may apply depending upon the amount of mercury in the bulb and applicable regulations, such as state or Environmental Protections Agency (EPA) rules.

Pulsed xenon ultraviolet light (PX-UV) room disinfection was introduced to the healthcare market in 2010 by Xenex Disinfection Services. (The highly portable device has been dubbed the “Germ-Zapping Robot.”) The Xenex system works by pulsing xenon, an inert gas, at high intensity from an ultraviolet flashlamp. This produces the full spectrum of germ-killing UV-C, which penetrates the cell walls of microorganisms, including bacteria, viruses, mold, fungus and spores. DNA is instantly fused so that microorganisms are unable to reproduce; PX-UV effectively kills these organisms on surfaces without contact or chemicals.

The full germicidal spectrum emitted by PX-UV eliminates a wide range of pathogens within five minutes at an efficiency rate of 99.9%. Treating most rooms involves two to three cycles, for a total of 10 to 15 minutes added to the time for the terminal cleaning process. It reaches soft surfaces such as drapes, as well as equipment that may be off-limits for housekeepers. Existing environmental services staff members are easily trained to use the robot. In many cases additional staff is not required to implement a Xenex program.

Xenex has tested its full spectrum UV on 22 microorganisms, studying nearly 2,000 samples in several independent labs all over the world. It is also able to deactivate non-enveloped viruses two meters away in any direction.

RESEARCH FINDINGS

PX-UV is the only environmental disinfection technology with multiple peer-reviewed research articles demonstrating the impact of the technology on actual infection rates. Some of the most significant research includes:

- A retrospective study of the effect of using Xenex following discharge cleaning of contact precautions rooms and other high-risk areas at Westchester Medical Center, a 643-bed academic medical center in Valhalla, NY, showed greatly reduced rates of hospital-onset MDROs and CDI (see table).*

<table>
<thead>
<tr>
<th>Organism</th>
<th>No. of cases</th>
<th>Rate/1,000 patient days</th>
<th>No. of cases</th>
<th>Rate/1,000 patient days</th>
<th>% change</th>
</tr>
</thead>
<tbody>
<tr>
<td>VRE</td>
<td>443</td>
<td>0.90</td>
<td>257</td>
<td>0.73</td>
<td>18.9%</td>
</tr>
<tr>
<td>C. difficile</td>
<td>390</td>
<td>0.79</td>
<td>228</td>
<td>0.65</td>
<td>17.7%</td>
</tr>
<tr>
<td>MRSA</td>
<td>224</td>
<td>0.45</td>
<td>116</td>
<td>0.33</td>
<td>26.7%</td>
</tr>
<tr>
<td>MDR*</td>
<td>260</td>
<td>0.52</td>
<td>148</td>
<td>0.42</td>
<td>19.2%</td>
</tr>
<tr>
<td>All HAs</td>
<td>1,320</td>
<td>2.67</td>
<td>749</td>
<td>2.14</td>
<td>20.6%</td>
</tr>
</tbody>
</table>

* Multiple-drug-resistant gram-negative bacteria

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• In July 2013, researchers at 140-bed Cooley Dickinson Hospital, Northampton, Massachusetts, reported a decrease of 53% in hospital onset CDI rates, as well as reductions in related deaths and colectomies, after hospital-wide implementation of Xenex.\textsuperscript{xi}

• PX-UV disinfection was found to be equivalent to bleach in reducing MRSA and bacterial heterotrophic plate counts (HPCs) on five high-touch surfaces in 20 patient rooms at Central Texas Veterans Health Care System, Temple, Texas.\textsuperscript{viii} In this study, one set of rooms was cleaned thoroughly with a bleach compound; the other set had only visible soil removed with bleach, followed by PX-UV disinfection. The HPC count was reduced by 76.3% in the manually cleaned rooms, and by 98.1% in rooms disinfected with Xenex; the MRSA count was reduced by 91.1% in the manual arm and by 99.4% in the PX-UV arm.

COMPARING UV TECHNOLOGIES

A 2015 study by a team from several northern Ohio hospitals examined the effectiveness of PX-UV for killing of \textit{C. difficile} spores, MRSA and VRE on glass surfaces and in rooms with high pathogen concentration.\textsuperscript{xiii} The study also examined factors such as the effective pathogen-killing distance of PX-UV and whether shading from the direct field of radiation had an effect on efficacy. In addition to controlled laboratory work, there were two phases of the study, one on uncleaned patient rooms; another on terminally cleaned patient rooms. Finally, the authors compared results on PX-UV with their earlier research on continuous UV radiation with mercury bulbs.

The study found that Xenex, used in two room locations for a total of 10 minutes, effectively reduced recovery of \textit{C. difficile} spores, MRSA and VRE in hospital rooms, including on high-touch areas (See table, below).

<table>
<thead>
<tr>
<th>PHASE 1: CONTAMINATION BEFORE AND AFTER PX-UV (WITHOUT TERMINAL CLEAN) *</th>
<th>C. difficile positive sites</th>
<th>MRSA (mean colony-forming units, or CFU)</th>
<th>VRE (mean CFU)</th>
<th>HPC (mean CFU)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Before</td>
<td>12%</td>
<td>9</td>
<td>21</td>
<td>522</td>
</tr>
<tr>
<td>After</td>
<td>3%</td>
<td>2</td>
<td>0</td>
<td>2</td>
</tr>
</tbody>
</table>

* Rooms did not previously house a \textit{C. difficile} patient but \textit{C. difficile} spores were recovered

<table>
<thead>
<tr>
<th>PHASE 2: CONTAMINATION BEFORE AND AFTER PX-UV (WITH TERMINAL CLEAN) *</th>
<th>C. difficile positive sites</th>
<th>MRSA (mean CFU)</th>
<th>VRE (mean CFU)</th>
<th>HPC (mean CFU)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Before</td>
<td>19%</td>
<td>96</td>
<td>12</td>
<td>934</td>
</tr>
<tr>
<td>After</td>
<td>8%</td>
<td>12</td>
<td>1</td>
<td>17</td>
</tr>
</tbody>
</table>

* 42% of phase 2 rooms previously housed a \textit{C. difficile} patient

EFFECT ON PATIENT SATISFACTION

A different kind of study was undertaken at Trinity Medical Center, a 320-bed acute general medical and surgical hospital located in Birmingham, Alabama.\textsuperscript{xiv} The study was designed to evaluate whether the introduction of Xenex had a positive impact on patient satisfaction.

Satisfaction was measured using the Hospital Consumer Assessment of Healthcare Providers and Systems (HCAHPS) survey. Cleanliness of the hospital environment is one of the questions included in the HCAHPS survey. In 2011, prior to the introduction of the Xenex system, HCAHPS scores for cleanliness and the overall rating of the hospital placed it below the national average. “After the introduction of the PX-UV system, the score for cleanliness and the overall rating of the hospital rose from below the 50th to the 99th percentile,” the study authors wrote. As a result of this improvement, the hospital received the maximum 1% of at-risk reimbursement from Medicare through the value-based purchasing program, totaling more than $1 million.

All the other nine HCAHPS parameters being measured, including communication and staff responsiveness, also improved over the same period. No other initiatives were introduced during this period, and there were no changes in staff or leadership.
RETURN ON INVESTMENT

Implementing PX-UV not only reduces the pathogens that caused infections, it also saves millions of dollars spent treating them costs that often cannot be recouped through reimbursement.

In August 2011, Cone Health, a multihospital system in Greensboro, North Carolina, announced results of research that found a new approach to infection control reduced the total number of HAIs by 42% from the first half of 2010 to the same period in 2011, leading to sizeable savings for the system.

The program included the use of Xenex’s automated room disinfection system; a renewed commitment to consistent hand hygiene for everyone; expanded MRSA surveillance testing; the addition of infection prevention professionals; the use of an electronic data mining system; and expanded education of personnel, patients and visitors.

“Using a combination of practices, tools and technologies, including Xenex’s room disinfection system, we were able to reduce our MRSA infections to zero in our ICUs,” said Terry Akin, Chief Operating Officer at Cone Health. “This has had the added benefit of saving the organization and community an estimated $2.3 million in infection-associated hospital costs. We consider the program a success.”

In June 2013 Cone Health published results showing the same approach had reduced the rate of all hospital-acquired MRSA infections at its three acute care hospitals by 56% during a six-month period from July 2011 to January 2012.1

CONCLUSION

Payment penalties for high rates of healthcare-associated infections, concerns over healthcare quality, new consumer awareness of hospital ratings and other factors are making inaction on HAIs increasingly problematic.

Standard cleaning regimens have been shown to be inadequate in removing the dangerous pathogens that may infect the next patient.

Xenex provides infection preventionists and environmental service teams with a powerful tool to significantly reduce potentially harmful microorganisms in the healthcare environment. Many of our customers have been able to implement Xenex without the need for additional staff and have seen only a slight increase in room cleaning times. Peer reviewed published studies demonstrate that disinfecting with Xenex is an effective means to reduce infection rates.

With the nature of payment penalties and legal settlements, avoiding even a handful of infections easily covers capital costs for Xenex and significant return on investment long into the future.

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Review Article

What Healthcare Workers Should Know about Environmental Bacterial Contamination in the Intensive Care Unit

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Intensive care unit- (ICU-) acquired infections are a major health problem worldwide. Inanimate surfaces and equipment contamination may play a role in cross-transmission of pathogens and subsequent patient colonization or infection. Bacteria contaminate inanimate surfaces and equipment of the patient zone and healthcare area, generating a reservoir of potential pathogens, including multidrug resistant species. Traditional terminal cleaning methods have limitations. Indeed patients who receive a bed from prior patient carrying bacteria are exposed to an increased risk (odds ratio 2.13, 95% confidence intervals 1.62–2.81) of being colonized and potentially infected by the same bacterial species of the previous patient. Biofilm formation, even on dry surfaces, may play a role in reducing the efficacy of terminal cleaning procedures since it enables bacteria to survive in the environment for a long period and provides increased resistance to commonly used disinfectants. No-touch methods (e.g., UV-light, hydrogen peroxide vapour) are under investigation and further studies with patient-centred outcomes are needed, before considering them the standard of terminal cleaning in ICUs. Healthcare workers should be aware of the role of environmental contamination in the ICU and consider it in the broader perspective of infection control measures and stewardship initiatives.

1. Introduction

Intensive care unit- (ICU-) acquired infections are a major health problem worldwide. Emergence of multidrug resistant organisms (MDROs) poses a daily challenge to ICU physicians, dealing with critically ill patients with multiple risk factors for infections (i.e., impairment of body barriers due to invasive devices and surgery, immunosuppression, prolonged antibiotic exposure) [1–4]. A relevant body of evidence highlights the high prevalence of contamination of high-touch surfaces and equipment surrounding patients' bed [5]. Indeed, the patient's nearby environment is crowded by equipment for monitoring and organ support (e.g., monitors, ventilator, extracorporeal life support machines), requiring sophisticated and specific cleaning procedures. Contamination of inanimate surfaces may occur as the consequence of direct patient shedding of bacteria (higher from infected than colonized patients) or via healthcare workers' (HCWs') hands. HCWs contaminate their hands from inanimate surfaces as frequently as direct patient contact [6]. In a randomized cross-over study, recontamination of high-touch surfaces in ICU occurred after only 4 hours from standard cleaning measures [7]. Environmental contamination in the ICU involves not only equipment for direct patient care (e.g., stethoscopes, ultrasound equipment, surfaces of mechanical ventilators) but also surfaces of objects used for clinical data recordings (i.e., medical charts, computer keyboard, and mouse) and mobile phones [8]. Environmental contamination has been identified as a major contributor of bacteria cross-transmission and patient colonization and infection. In 1991, Weinstein [9] estimated the relative contribution of different potential sources for ICU-acquired infections: 40–60% patient's endogenous flora, followed by cross-infection via HCWs' hands (20–40%), antibiotic-driven changes in flora.
Figure 1: Patient zone with more frequently isolated bacteria contaminating inanimate surfaces and equipment.

(20–25%), and other sources (including environmental contamination, 20%). Understanding the mechanisms underlying cross-transmission of pathogens from inanimate surfaces and equipment may contribute to lay the foundation of effective infection control measures aiming to halt the spread of healthcare-associated infections. The aim of this review is to provide updated evidence on environmental contamination in the ICU, focusing on mechanisms by which bacteria are able to survive on inanimate surfaces, describing the concept of patient zone and healthcare area and the role of contamination for ICU-acquired colonization and infection.

1.1. The Concepts of Patient Zone and Healthcare Area. The concepts of patient zone and healthcare area have been introduced as a user-centred, operative behaviour aiming to enhance hand hygiene compliance [10]. The patient zone encompasses the patient and surfaces and equipment surrounding him/her (i.e., bed rails, ventilator, monitors). The healthcare area is composed of all surfaces outside a given patient zone (i.e., the healthcare facility environment and other patient zones) [8].

The healthcare area may be contaminated by bacteria from different patient zones. Inanimate surfaces in the patient zone are contaminated by bacteria colonizing/infecting patients in two ways: direct shedding from patients and via HCWs’ hands. High-touch objects in the immediate vicinity of patients are heavily contaminated. A higher degree and rate of contamination occur from infected patients than from patients who are only colonized. Moreover, a correlation exists between number of culture-positive body sites and environmental contamination [11, 12]. A high degree of patient zone contamination has been reported also in case of patients with diarrhea [13, 14].

Figure 1 shows a patient zone with most frequently reported contaminating bacteria in the literature.

1.2. ICU-Acquired Colonization and Infection: Update on Available Evidence. Evidence on the role of environmental contamination for cross-transmission of pathogens comes from studies reporting on outbreaks of infections driven by contaminated objects or equipment, studies investigating the association of colonized/infected patients with environmental and HCWs’ hands contamination, and studies reporting on the risk of acquiring bacteria from prior bed occupants [15]. Hand-washing sinks, bottled still water, and bronchoscope suction valves have been related to outbreaks registered in ICUs, with the same strains and antibiotic susceptibility profiles registered in those isolated from colonized/infected patients [16–21]. This observation is of value when we
consider the role of inanimate surfaces contamination as a reservoir of MDROs of potentially pathogen role.

In their cohort study, Morgan et al. [22] investigated how frequently HCWs contaminated gloves and gowns after contact with patients. Approximately, after one of every three interactions with a patient carrying *Acinetobacter baumannii*, HCWs contaminated their gloves and gowns. *A. bauman- nii* was present in almost 80% of rooms from colonized/infected patients. Contamination with *A. baumannii* occurred more frequently than with other bacteria (*Pseudomonas aerugi- nosa*, vancomycin-resistant Enterococci and metchillin-resistant *Staphylococcus aureus*). Independent risk factors for HCWs contamination by MDROs were positive environmental cultures (OR 4.2, 95% CI 2.7–6.5), stay in room for more than 5 minutes (OR 2.0, 95% CI 1.2–3.4), performing physical examination (OR 1.7, 95% CI 1.1–2.8), and contact with the ventilator (OR 1.8, 95% CI 1.1–2.8) [22].

A number of studies reported on a higher risk of acquiring bacteria from prior room occupants. This independent risk factor occurred for both Gram-positive (*S. aureus, Enterococcus species, Clostridium difficile*) and Gram-negative bacteria (*Acinetobacter spp., P. aeruginosa, Klebsiella pneumo- niae*) [23], including MDROs (MRSA, VRE). We recently performed a meta-analysis of studies investigating this issue in the ICU setting [24]. The pooled OR of acquisition of bacteria from prior bed occupants was 2.13 (95% CI 1.62–2.81). When we considered the OR for the acquisition according to bacterial species, we registered the highest OR for *A. baumannii* (OR 4.91, 95% CI 2.79–8.64) and *C. difficile* (OR 2.57, 95% CI 1.28–5.15). It is remarkable that this increased risk occurs even when current terminal cleaning procedures are addressed. We may speculate that these findings may be explained by suboptimal terminal cleaning procedures resulting in persisting surfaces contamination. Environmental contamination may represent the reservoir for cross-transmission of bacteria via HCWs’ hands. Structural ICU features may be associated with a different degree of environmental contamination and cross-transmission rate. Indeed, single-room ICUs have the theoretical advantage of a physical separation of different patient zones. This may be also associated with the ease of adoption of enhanced terminal cleaning procedures requiring environment isolation. However, cross-transmission of bacteria from prior bed occupant occurred in single-room ICUs in most studies [25].

### 1.3. Terminal Cleaning in ICU

The term terminal cleaning refers to all methods used for disinfection of either a room or a patient zone between occupying patients (i.e., after patient discharge). Quaternary ammonium and bleach are the most commonly used products for this purpose. The efficacy of terminal cleaning relies on different factors, including training and management of personnel (e.g., adequate contact time, compliance with protocols) and accessibility of surfaces. If we consider the higher patient’s risk of acquiring a MDRO if exposed to the bed of a previously colonized/infected patient, current terminal cleaning methods are far from being considered a highly effective procedure. Inadequate cleaning as assessed by objective measures of operators’ performance has been reported in different studies. Programs including

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The text continues with a discussion on how frequently HCWs contaminate their gloves and gowns after contact with patients, and the risk factors for this contamination. It also explores the theoretical advantages of single-room ICUs in preventing cross-transmission of bacteria. The text further delves into the efficacy of terminal cleaning methods and the need for more effective procedures.
with bleach, bleach, and reference (quaternary ammonium). Notably, according to their standard cleaning protocol, bleach was used as reference for rooms seed by \textit{C. difficile}. Adding UV-light led to a reduction of the incidence of colonization and infection caused by MRSA and VRE, while authors did not observe a statistically significant difference when UV-light was compared to bleach. Of note, only one outcome occurred for \textit{Acinetobacter} and therefore the role of enhanced terminal cleaning was not investigated for this pathogen. The lack of benefit for \textit{C. difficile} cross-transmission was explained by the adoption of an enhanced procedure also in the reference group (i.e., bleach), the high compliance of personnel to the cleaning protocol (which may be significantly lower in real life), and the use of a single-stage cycle of UV-light for a pathogen with a time- and dose-dependent response to UV-light. Despite these limitations, this is the first trial to date enrolling such a high number of patients and adopting the clinically relevant outcomes of infections and colonization [35].

H$_2$O$_2$ is a noncorrosive agent showing bactericidal, fungicidal, sporicidal, and virucidal properties in vitro. H$_2$O$_2$ damages lipid membranes, DNA, and RNA through its oxidative action. HPV showed effective decontamination against MRSA, VRE, \textit{Acinetobacter} spp., \textit{K. pneumonia}, and \textit{C. difficile} spores [36]. H$_2$O$_2$ may be released in three different forms: dry vapour, wet vapour, and mist. These three technologies produce H$_2$O$_2$ particles small enough to diffuse and reach hidden and difficult to reach surfaces. Recently, Blazejewski et al. [37] investigated the efficiency of HPV in improving disinfection in ICUs. They applied HPV after routine terminal cleaning and collected environmental sampling before and after HPV use. After patient discharge, 8% of sampled rooms were contaminated with at least 1 MDRO. Routine terminal cleaning reduced the environmental bacterial load but authors did not detect a statistically significant difference in the degree of MDROs contamination [37]. HPV, instead, significantly reduced the residual environmental contamination by MDROs. Given the high costs for implementation of no-touch terminal cleaning methods in ICUs (i.e., machines and maintenance costs, additional staff members), further studies are needed to evaluate their impact for patient-centred outcomes.

2. How Bacteria Survive on Inanimate Surfaces and after Terminal Cleaning Procedures?

The principal factors associated with the ability of a nosocomial pathogen to survive on inanimate surfaces and equipment are the specific microorganism characteristics (such as genus, species, specific strain, ability to form biofilm, and microorganism concentration) and the environmental factors (such as UV radiation, temperature, humidity, presence of organic materials, and surface type) [38–40]. Evidence on the capacity to survive in environmental reservoirs has been reported for bacteria (\textit{C. difficile}, \textit{VRE}, MRSA, \textit{P. aeruginosa}, \textit{Escherichia coli}, \textit{Klebsiella} spp., and \textit{Acinetobacter} spp.); viruses (influenza, parainfluenza, enteric, hepatitis B viruses), and fungi (\textit{Candida albicans}, \textit{Candida glabrata}, \textit{Candida parapsilosis}, \textit{Aspergillus} spp., and Zygomyces) [41–47].

Microorganisms are able to survive on surfaces because of their production of adhesion molecules and biofilms. These abilities are favoured when microorganisms grow on materials with high absorptive capacity [48]. Coagulase-negative staphylococci are able to survive up to 8–21 days on cotton used to produce clothing and towels, while \textit{P. aeruginosa} survives for only 2–24 hours on the same surface. Even different species from the same genus showed different survival capacity [42]. As an example, \textit{C. parapsilosis} showed higher resistance when compared to \textit{C. albicans} or \textit{C. krusei} [49]. Intrinsic microbiologic features also influence the resistance against disinfectants. For example, mycobacteria have a waxy cell wall able to prevent disinfectants entry, whereas Gram-negative bacteria have an outer membrane acting as a barrier preventing the uptake of disinfectants [50]. Concentration of Gram-positive and Gram-negative bacteria, fungi, and viruses may influence their persistence on surfaces; the greater the microbial load, the longer the survival capacity. A biofilm is a structured community of microorganisms encased and attached to surfaces by exopolymeric substances (EPS). Up to 90% of biofilm are made of EPS, which provides protection against environmental desiccation. Biofilm plays an important role in catheter-related infections and of other indwelling medical devices [51]. Bacteria are able to form biofilm also on dry inanimate surfaces. It has been speculated that biofilm formation may be enhanced by a thin film of water resulting from condensation on surfaces or that the relative humidity of ICUs is sufficiently high to allow biofilm formation [52]. Biofilms contain a high bacterial load able to survive on dry hospital surfaces for a long time, showing also an increased resistance towards inactivation by disinfectants. Indeed, bacteria in the biofilm are up to 1000-fold more resistant to disinfectants than their corresponding planktonic form [40, 52–55]. \textit{P. aeruginosa} biofilm on flexible endoscopes surfaces is able to survive 5-minute treatment with peracetic acid at 2000 parts per million concentration, which is the working concentration used by some washer-disinfectors [54].

Vickery et al. [52] investigated the persistence of reservoirs of MDROs within biofilm after terminal cleaning in an ICU. Equipment and furnishings were aseptically removed from the ICU, scanned by electron microscopy and cultured. Biofilm was demonstrated on 4 of the five different samples from the patient zone and healthcare area. Cultures from samples led to MRSA growth. This finding highlights one possible explanation of the suboptimal terminal cleaning efficacy and the persistence of a reservoir of MDROs possibly involved in direct or indirect (via HCWs’ hands) cross-transmission [52]. This should be considered in the broader perspective of emergence of MDROs, stewardship initiatives, and infection control measures [45, 56–58].

The increased resistance of biofilms to disinfectants is supposed to be due to the following factors:

(i) gene regulation of microorganisms with increased lateral gene transfer and mutation rates [59];

(ii) phenotypic adaptation of cells to sublethal disinfectant concentration [60];
Among environmental variables, ultraviolet (UV) light, temperature, humidity, and presence of organic material have been reported to have a major role in influencing microbial viability. Visible light and UV radiation are generally deleterious to microorganisms. Temperatures higher than 50°C are able to kill most Candida spp., while low temperatures (4°C to 6°C) increase survival times for many bacteria. Humidity can have variable effects on the persistence of microorganisms on surfaces. Yeast showed a better survive at higher humidity [42]. Organic matter (e.g., blood, serum, sputum, pus, fecal material) may play both a direct and an indirect role to enhance environmental resistance of microorganisms. The direct role is the barrier effect protecting microorganisms from environmental physical and chemical agents. The indirect role is the interference of organic matter with the antimicrobial activity of disinfectants through chemical reactions resulting in a complex exhibiting less germicidal or nongermicidal properties and leaving a reduced quantity of active disinfectant agents. This frequently occurs with chlorine and iodine disinfectants [63]. In parallel with development of new strategies to enhance disinfectant agents’ efficacy, different research groups are now focusing on development of novel materials which may potentially be used to prevent or reduce contamination and biofilm formation by bacteria, including MDROs. Metal-embedded surfaces (copper, gallium, and titanium) were effective at preventing planktonic and biofilm growth of P. aeruginosa, S. aureus, and E. coli tested strains [64]. In a recently published observational study, silver-embedded screens used to separate ICU beds were more effective than traditional cloth screens at reducing surfaces contamination and cross-transmission of pathogens [65].

3. Conclusions

Inanimate surfaces and equipment contamination play a major role in cross-transmission of pathogens in ICUs. Bacteria, including MDROs, may survive for a long time to environmental physical and chemical agents and have been isolated from different surfaces and equipment of the patient zone and of the healthcare area [8]. Traditional terminal cleaning methods showed major flaws and no-touch methods are under investigation [24, 34]. Clinicians should be aware of the issue of environmental contamination and consider it in the broader perspective of infection control measures and stewardship initiatives [58].

Conflicts of Interest

The authors declare no conflicts of interest.

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Impact of pulsed xenon ultraviolet disinfection on surface contamination in a hospital facility’s expressed human milk feed preparation area

Ricky Dippenaar and Johan Smith

Abstract

Background: Expressed human milk (EHM) feed preparation areas represent a potential source of unintentional nosocomial infection. Daily disinfection of environmental surfaces remains an essential intervention to mitigate nosocomial infections. The inefficiency of conventional cleaning and disinfection contributes to an increased risk for the acquisition of multi-drug resistant pathogens. “Non touch” technologies such as the pulsed xenon ultraviolet (PX-UVD) light device have documented sustained reduction in surface bacterial colonization and reduced cross contamination.

Methods: The impact of a PX-UVD on surface colony forming units per square centimeter (cfu/cm²) in feed preparation areas was evaluated following its implementation as standard care. A quasi-experimental study was performed documenting bacterial colonization from 6 high risk feed preparation areas in a community care hospital in South Africa. Pre and post conventional cleaning neutralizing rinse swabs were collected fortnightly over a 16 week control period prior to the introduction of the PX-UVD and compared to a matching set of samples for the PX-UVD period.

Results: A 90% reduction in total surface bioburden was noted from the control period (544 cfu/cm²) compared to the corresponding PX-UVD period (50 cfu/cm²). Sub-analysis of both the Pre-clean Control: Pre-clean PX-UVD counts as well as the Post-clean Control: Post-clean PX-UVD counts noted significant improvements ($p < 0.001$). A statistically significant improvement was noted between pre-and post-cleaning total surface bioburden following exposure to the PX-UVD ($p = 0.0004$). The introduction of the PX-UVD was associated with a sustained reduction in the pre clean bioburden counts with a risk trend (per week) 0.19, (95% CI [0.056, 0.67], $p = 0.01$).

Discussion: The use of a PX-UVD as adjunct to standard cleaning protocols was associated with a significant decrease in surface bioburden. The study demonstrated the inefficiency of conventional cleaning. Persistence of potentially pathological species in both periods highlights current health sector challenges.

Keywords: Feed preparation areas, Hospital infection, Bioburden, Non touch disinfection, Pulsed xenon ultraviolet
inefficiency of recognized cleaning and disinfection practices remains concerning [4]. Mitchell et al., 2015, found that failure to adequately disinfect high risk areas contributes to an increased risk for the acquisition of multi-drug resistant pathogens [5]. The inclusion of “non touch” room disinfection technology represents a proven adjunct to any facility’s disinfection SOP aimed at addressing potential shortcomings [6].

The pulsed xenon ultraviolet (PX-UVD) light device is a “non touch” ultraviolet C (UV-C) emitting technology designed for the hospital setting. Each pulse from the non-mercury Xenon flash lamp releases approximately 505 J of energy into high intensity broad-spectrum UV light, with a narrow band concentration within the UV-C spectrum [7]. The germicidal effects of UV-C irradiation (200–300 nm) results in cellular damage by photohydration, photosplitting, photodimerization and photo crosslinking, thereby inhibiting cellular replication [8]. Implementation of this “non touch” technology in various hospitals has documented a sustained reduction in surface bacterial colonization [9], reduced cross contamination [10] and reduced spread of multi drug resistant bacterial infections in settings other than a feed preparation area [11, 12].

Method

Aim

The aim of this study was to evaluate the effect of a pulsed-xenon ultraviolet portable device (PX-UVD) as compared to standard care on surface colony forming units per square centimeter (cfu/cm²) within neonatal and pediatric EHM feed preparation areas at Netcare Blaauwberg hospital.

Study setting

Netcare Blaauwberg private hospital is a 140 bed acute care community hospital in the Western Cape of South Africa, with a 12 bed neonatal intensive care unit (NICU), a 16 bed pediatric ward and a 16 bed maternity ward.

The NICU, maternity and pediatric wards actively participate in the baby friendly initiative promoting human milk exclusivity. The NICU utilizes a multi counter dedicated expressed human milk (EHM) feed preparation area for the processing of stored fresh and frozen EHM. The maternity and pediatric wards have a dedicated single counter feed preparation area. Reconstitution of dry milk formulae only occurs within the pediatric and maternity wards on strict prescription of the attending pediatricians.

Design

A quasi-experimental study was conducted from June 2015 until February 2016. The study was approved as a nonhuman-subject, quality-improvement study by the Netcare research operations committee and the University of Stellenbosch ethics committee.

Sample

Environmental surface bioburden was evaluated by collecting pre – and post cleaning surveillance swabs from 6 surfaces in 3 feed preparation areas using pre-immersed neutralizing rinse swabs (NRSII™ Transwab™). The six high risk areas identified included; the NICU prewash EHM bottle area, the NICU post-wash EHM bottle area, the NICU EHM preparation area, the NICU fridge door handle and the single counter surface within the feed preparation areas of both the pediatric and maternity wards.

Pre cleaning swabs were collected fortnightly at 7 am for the duration of the study. The study coordinator determined the day of the week for sampling using a simple sealed envelope randomization system which was then relayed to the head of infection control. The head of infection control performed all sampling for the study duration. All sampling was standardised to a single predetermined 10 cm (cm) × 10 cm area for each surface as per the recommendation of the resident clinical microbiologist.

Following pre clean sampling, the area was cleaned as per the facility’s SOP. The facility’s SOP for daily terminal cleaning of working surfaces in the feed preparation areas involves initial cleaning with soap and water using commercially available disposable cloths, followed by disinfection with a suspension of Troclosene Sodium (NaDCC) at 500 ppm (ppm). Cleaning of the fridge door and handle is a specifically allocated area and includes the aforementioned protocol in addition to weekly cleaning of the inside of the fridge and monthly defrosting. One designated trained multi-shift cleaning team is allocated to this duty on a continuous basis. The area is then allowed to air dry for 1 h after which post cleaning swabs were taken from the same allocated areas.

Cleaning staff and nursing staff were blinded to the details of the study as well as to the timing of the swabs, allocated areas and frequency of sampling. The facility’s head of infection control and resident microbiologist remained blinded to the sample results for the duration of the study.

Measurement

A total of 108 CONTROL samples were collected fortnightly over a 16 week period prior to the implementation of the PX-UVD on week 17 of the study. The introduction of the PX-UVD to the standard cleaning protocol involved the daily cleaning of the allocated feed preparation areas as per facility’s SOP including an air dry period for 1 h. Thereafter the PX-UVD was placed on either side of each of the 3 feed preparation areas for a 5-min treatment cycle, as per manufacturers recommendations. Post cleaning swabs were taken immediately after exposure to the PX-UVD. A matching 108 PX-UVD samples was collected over the ensuing 16 weeks.
Environmental testing procedure
The pre-immersed neutralizing rinse swabs (NRSII™ Transwab ™) were immediately collected and transported by Pathcare laboratory services in a temperature regulated environment for processing at their off-site facility. Each swab container underwent mixing by vortexing 1 ml of neutralizing rinse solution which was then placed on a total viable count (TVC) Petrifilm (3 M Rehydratable film method) agar. Petrifilm agars were then incubated at 35°C ± 2°C for 48 ± 3 h. The total viable count was then quantified into number of colony forming units per square centimeter (cfu/cm²). The colonies cultured, included both natural environmental contaminant species as well as potentially pathogenic species, were then transferred to agar plates for further organism identification.

Device
A single PX-UVD (Xenex Disinfection Services, San Antonio, Texas) was received on loan from Kiara Healthcare for the duration of the 4-month study period. Floor plans, counter heights, and room dimensions were relayed to the manufacturer. The optimal efficacy for the device was mathematically modelled based on spectrometer data and the location and size of the target areas. The resulting recommendation of two treatment cycles of 5-min per side of each allocated feed preparation area was determined to ensure maximum counter exposure with no shadow areas.

Data analysis
Total surface bioburden was calculated as the sum of the viable colony count (cfu/cm²) of the 6 counter surfaces in the pre and post cleaning phases. Statistical analyses was performed using the NCSS statistical analysis package (NCSS 11 Statistical Software (2016). NCSS, LLC. Kaysville, Utah, USA.)

Numerical data was log transformed to achieve normality. A multi-variance ANOVA analysis was applied to the log sample data to determine statistical relevance and trend analysis. The log data was back transformed and the observed geometric mean differences represented as risk ratios.

Results
A 90% reduction in total surface bioburden was noted from the control period (544 cfu/cm²) compared to the corresponding PX-UVD period (50 cfu/cm²). Pre cleaning surface bioburden significantly improved from 244 cfu/cm² in the CONTROL period to 44 cfu/cm² in the PX-UVD period with a geometric mean risk ratio 0.11, (95% CI [0.04, 0.29], p < 0.001). Similarly, the post cleaning surface bioburden significantly improved from 300 cfu/cm² in the CONTROL period to 6 cfu/cm² in the PX-UVD period with a geometric mean risk ratio 0.04, (95% CI [0.02, 0.09], p < 0.001). Individual counter surface data during the CONTROL period noted higher average surface bioburden within areas of the NICU, most notably the post-wash EHM bottle area and the EHM preparation area recorded higher surface bioburden counts post conventional cleaning. (Table 1) The highest average surface bioburden count was consistently measured on the Fridge door handle. Individual counter surface data for the matching PX-UVD period demonstrated a sustained improvement post cleaning as well as significantly reduced average surface bioburden counts across all surfaces measured (Table 1).

The graphical representation of the CONTROL period (Fig. 1) demonstrates an inconsistent response to conventional cleaning including a worsening of the post cleaning total surface bioburden in weeks 4 and 10. The introduction of the PX-UVD at 17 weeks was initially associated with a dramatic reduction in both the pre and post cleaning total surface bioburden, followed by a sustained reduction in the pre clean surface bioburden counts with a risk trend (per week) 0.19, (95% CI [0.056, 0.67], p = 0.01). (Figure 1) Furthermore, in contrast to the CONTROL period (geometric mean risk ratio 0.08, (95% CI [0.24, 1.10], p = 0.08) a statistically significant improvement was demonstrated between the pre cleaning total surface bioburden and the post cleaning total surface bioburden following exposure to the PX-UVD (geometric mean risk ratio 0.19, (95% CI [0.09, 0.40], p = 0.00004)), including complete eradication of detectable bacteria in weeks 18 and 28.

Twenty three pathological organisms were identified during the control period in comparison to the 5 identified during the PX-UVD period (Table 2).

Discussion
Expressed human milk, particularly within the confines of the high-risk environment of the neonatal ICU, represents a critical irreplaceable aspect of the care for these highly vulnerable and immunocompromised infants. Ensuring a sterile dedicated environment for the processing and handling of EHM cannot be overemphasized. Despite our compliance with the South African Department of Health’s and facility’s recommendations for surface disinfection, this study highlighted the inefficiency of conventional cleaning on both natural environmental contaminants and potentially pathogenic species. The significantly higher total surface bioburden counts and increased post clean total surface bioburden counts during the control period invariably contributed to the diversity of potentially pathogenic isolates identified during this period.

The introduction of a “no-touch” PX-UVD as an adjunct to the facility’s conventional cleaning SOP was associated initially with a dramatic reduction in both the pre and post clean total surface bioburden. Subsequently, a sustained
reduction in the pre clean surface bioburden counts together with a stabilization and consistent improvement between the pre- and post cleaning surface bioburden, culminated in a statistically significant reduction in pre and post cleaning total surface bioburden for the PX-UVD period. The susceptibility of both environmental contaminants and potentially pathogenic organisms to the germicidal effects of UV-C exposure remains cautiously reassuring of the potential long term sustained effects of PX-UVD.

The relative dominance of potentially pathogenic gram-negative isolates, as opposed to gram-positive organisms such as Clostridia difficile and Methicillin-resistant Staphylococcus aureus with documented sensitivity to UV-C [4–7], was presumably the effect of study design, focussing on the neonatal, maternity and paediatric wards with a relatively low facility prevalence. The persistence of the Acinetobacter species in both the CONTROL and PX-UVD periods highlights the challenges the health sector is facing despite the inclusion of newer disinfection solutions and technologies; further hampered by multiple reports of resistance of this genus to conventional disinfection solutions [13] and documented varying susceptibility of microorganisms to ultraviolet disinfection [14].

**limitations**

The limitations of this study include the relatively small study numbers, limited study duration and the lack of variability of performing a single institution study. We did not evaluate the potential long term cumulative suppressive effects following the introduction of the PX-UVD as well as its impact on both environmental and potentially pathogenic organisms; nor the potential impact of a lower surface bioburden and its effect on nosocomial infection rates.

Despite these limitations, as a quality improvement study, several strategies have been strongly recommended and subsequently implemented. Expressed human milk feed preparation areas have been deemed

---

**Table 1 Geometric mean (GM) of colony counts per sample area**

<table>
<thead>
<tr>
<th>Area</th>
<th>Control PreClean GMa</th>
<th>Control PostClean GMa</th>
<th>Δ GMb</th>
<th>Risk Ratio</th>
<th>95% CI</th>
<th>p-value</th>
<th>PX-UVD PreClean GMa</th>
<th>PX-UVD PostClean GMa</th>
<th>Δ GMb</th>
<th>Risk Ratio</th>
<th>95% CI</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>PreWashBottle</td>
<td>0.37</td>
<td>0.04</td>
<td>0.33</td>
<td>0.09</td>
<td>0.01</td>
<td>0.61</td>
<td>0.01</td>
<td>0.02</td>
<td>0.03</td>
<td>0.33</td>
<td>0.05</td>
<td>0.2395</td>
</tr>
<tr>
<td>PostWashBottle</td>
<td>0.58</td>
<td>1.68</td>
<td>1.10</td>
<td>2.89</td>
<td>0.44</td>
<td>18.85</td>
<td>0.2646</td>
<td>0.07</td>
<td>0.07</td>
<td>0.10</td>
<td>0.02</td>
<td>0.0188</td>
</tr>
<tr>
<td>EHMprep</td>
<td>0.65</td>
<td>0.78</td>
<td>0.13</td>
<td>1.19</td>
<td>0.18</td>
<td>7.77</td>
<td>0.8533</td>
<td>0.09</td>
<td>0.07</td>
<td>0.23</td>
<td>0.03</td>
<td>0.1187</td>
</tr>
<tr>
<td>FridgeDoorHandle</td>
<td>1.23</td>
<td>1.15</td>
<td>0.08</td>
<td>0.93</td>
<td>0.14</td>
<td>6.09</td>
<td>0.9432</td>
<td>0.14</td>
<td>0.10</td>
<td>0.28</td>
<td>0.04</td>
<td>0.1820</td>
</tr>
<tr>
<td>Maternity</td>
<td>0.81</td>
<td>0.18</td>
<td>0.63</td>
<td>0.22</td>
<td>0.03</td>
<td>1.44</td>
<td>0.1138</td>
<td>0.16</td>
<td>0.15</td>
<td>0.03</td>
<td>0.00</td>
<td>0.0003</td>
</tr>
<tr>
<td>Pediatric</td>
<td>0.45</td>
<td>0.12</td>
<td>0.33</td>
<td>0.27</td>
<td>0.04</td>
<td>1.78</td>
<td>0.1727</td>
<td>0.02</td>
<td>0.01</td>
<td>0.06</td>
<td>0.11</td>
<td>0.6948</td>
</tr>
</tbody>
</table>

*a geometric mean (GM), b difference in geometric mean (Δ GM), c Confidence Interval (CI)*

---

![Fig. 1 Log transformed mean bioburden over weeks](image-url)
Table 2 Organisms identified

<table>
<thead>
<tr>
<th>Control</th>
<th>PX-UVD</th>
</tr>
</thead>
<tbody>
<tr>
<td>7 Acinetobacter baumannii</td>
<td>3 Acinetobacter baumannii</td>
</tr>
<tr>
<td>4 Enterobacter cloacae</td>
<td>1 Acinetobacter ursingii</td>
</tr>
<tr>
<td>4 Stenotrophomonas maltophilia</td>
<td>1 Klebsiella teringa</td>
</tr>
<tr>
<td>2 Aeromonas hydrophilia</td>
<td>1 Klebsiella pneumoniae</td>
</tr>
<tr>
<td>1 Enterococcus casseliflavus</td>
<td>1 Klebsiella pneumoniae pneumoniae</td>
</tr>
<tr>
<td>1 Faivalmonas oźlyhabitans</td>
<td>1 Senata marcescens</td>
</tr>
<tr>
<td>1 Klebsiella pneumoniae caenza</td>
<td>1 Senata liquifaciens</td>
</tr>
</tbody>
</table>

high priority areas. The facility’s SOP has been amended to include the conversion to a commercially available quaternary ammonium disinfection solution to negate the potential risk of over-dilution of NaDCC, nonwoven microfiber spunlace cloths have replaced the commercially available disposable cloths for disinfection and the specialized cleaning teams have been re-educated emphasizing on key impact measures such as disinfectant contact time. In addition, a quality assurance monitoring system using adenosine triphosphate (ATP) bioluminescence was introduced to evaluate cleaning practices within the EHM feed preparation area, providing feedback to the specialized cleaning teams. The acquisition and permanent inclusion of a PX-UVD as standard care has been strongly recommended.

Conclusion
The use of a PX-UVD as an adjunct to the facility’s standard cleaning protocols within the EHM feed preparation areas was associated with a significant decrease in surface bioburden. Future long term studies are envisioned to evaluate the relationship of a reduced surface bioburden and its impact on nosocomial infection, particularly within neonatal ICU.

Acknowledgements
The authors would like to thank Kiara Healthcare for the training and access to the PX-UVD for the duration of the study at no cost as well as the Netcare private hospital group for allowing the research to be conducted with this device at one of their institutions.

Funding
Independent laboratory services and statically analysis was funded from an independent practice research fund.

Data
The datasets used and/or analysed during the current study are available from the corresponding author on reasonable request.

Authors’ contributions
RD and JS were both involved in the study design. RD was the study coordinator, ensuring randomisation of day of sampling from sealed envelope system, collection and collation of data from independent laboratory and transfer of data to the independent statisticians. RD and JS wrote and edited the manuscript. All authors read and approved the final manuscript.

Ethics approval and consent to participate
The study was approved as a nonhuman-subject, quality-improvement study by the Netcare research operations committee and the approval waived by the University of Stellenbosch ethics committee.

Consent for publication
Not applicable.

Competing interests
The authors declare that they have no competing interests.

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References


EBOLA VIRUS EFFICACY TESTING

OVERVIEW

Ebola virus testing is performed only by Biosafety Level 4 laboratories (BSL-4), the highest biocontainment level labs which are reserved for the most hazardous infectious agents. Less than 15 such labs exist in the United States. The Texas Biomedical Research Lab is a BSL-4 lab located in San Antonio, Texas, where Xenex pulsed xenon UV light was tested against Ebola virus.

METHOD

To test the antiviral effects of UV exposure on Ebola virus, 20 µL of virus was dried onto to a chamber slide. After drying, samples were positioned vertically at a distance of 1 meter and exposed to UV light generated by the Xenex robot for various time lengths. Virus was re-suspended and harvested from the slide and infectious virus remaining was quantified by plaque assay.

RESULTS SUMMARY

No virus was detected on the test samples and are therefore considered below the limit of detection for the assay (3.75E2 PFU/mL).

Control 1 was treated identically to the test samples in the absence of UV exposure.

Control 2 was a positive control to test starting virus concentration.

<table>
<thead>
<tr>
<th>Sample ID</th>
<th>Distance (m)</th>
<th>UV Contact Time (min)</th>
<th>Titer (pfu/mL)</th>
</tr>
</thead>
<tbody>
<tr>
<td>CS1</td>
<td>1</td>
<td>1</td>
<td>BLD</td>
</tr>
<tr>
<td>CS2</td>
<td>1</td>
<td>1.5</td>
<td>BLD</td>
</tr>
<tr>
<td>CS3</td>
<td>1</td>
<td>5</td>
<td>BLD</td>
</tr>
<tr>
<td>CS4</td>
<td>1</td>
<td>10</td>
<td>BLD</td>
</tr>
<tr>
<td>Control 1</td>
<td>NA</td>
<td>NA</td>
<td>1.85E+07</td>
</tr>
<tr>
<td>Control 2</td>
<td>NA</td>
<td>NA</td>
<td>1.57E+07</td>
</tr>
</tbody>
</table>

There was at least a 4.9E4 (4.9 log) reduction in infectivity following exposure to UV (1.85E7/3.75E2) in 1 meter at 1 minute.

Note: Efficacy testing outside of a BSL-4 lab uses a virus surrogate and not the actual Ebola virus. Any company claiming to have tested their disinfection efficacy against Ebola should provide details of the actual virus used.
Evaluation of a pulsed-xenon ultraviolet room disinfection device for impact on contamination levels of methicillin-resistant Staphylococcus aureus

Chetan Jinadatha1*, Ricardo Quezada2, Thomas W Huber1, Jason B Williams3, John E Zeber1,2 and Laurel A Copeland1,2

Abstract

Background: Healthcare-acquired infections with methicillin-resistant Staphylococcus aureus (MRSA) are a significant cause of increased mortality, morbidity and additional health care costs in United States. Surface decontamination technologies that utilize pulsed xenon ultraviolet light (PPX-UV) may be effective at reducing microbial burden. The purpose of this study was to compare standard manual room-cleaning to PPX-UV disinfection technology for MRSA and bacterial heterotrophic plate counts (HPC) on high-touch surfaces in patient rooms.

Methods: Rooms vacated by patients that had a MRSA-positive polymerase chain reaction or culture during the current hospitalization and at least a 2-day stay were studied. 20 rooms were then treated according to one of two protocols: standard manual cleaning or PPX-UV. This study evaluated the reduction of MRSA and HPC taken from five high-touch surfaces in rooms vacated by MRSA-positive patients, as a function of cleaning by standard manual methods vs a PPX-UV area disinfection device.

Results: Colony counts in 20 rooms (10 per arm) prior to cleaning varied by cleaning protocol: for HPC, manual (mean = 255, median = 278, q1-q3 132–304) vs PPX-UV (mean = 449, median = 365, q1-q3 332–530), and for MRSA, manual (mean = 127; median = 28.5; q1-q3 8–143) vs PPX-UV (mean = 108; median = 123; q1-q3 14–183). PPX-UV was superior to manual cleaning for MRSA (adjusted incident rate ratio [IRR] = 7; 95% CI <1–41) and for HPC (IRR = 13; 95% CI 4–48).

Conclusion: PPX-UV technology appears to be superior to manual cleaning alone for MRSA and HPC. Incorporating 15 minutes of PPX-UV exposure time to current hospital room cleaning practice can improve the overall cleanliness of patient rooms with respect to selected micro-organisms.

Keywords: MRSA, Methicillin-resistant Staphylococcus aureus, No touch disinfection, Pulsed xenon ultraviolet disinfection device, Nosocomial infections

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Background

Healthcare-acquired infection (HAI) with methicillin-resistant Staphylococcus aureus (MRSA) is a significant cause of mortality and morbidity in the United States accounting for up to $9.7 billion annually in additional health care costs, and €44.0 million annually in Europe [1,2]. In the Americas, Europe, and parts of Africa and Asia, MRSA is the predominant multi-drug resistant microbe, making it a global concern of escalating importance in terms of cost and patient safety [3]. Combating MRSA with new pharmaceutical agents offers only short-term solutions; unconventional approaches may comprise a more effective solution to drug-resistant infectious microbes [4].

Patients admitted to rooms vacated by MRSA-positive patients have higher relative risk of acquiring MRSA [5,6]. In a 2009 review of environmental cleaning studies, Dancer concluded that high-touch surfaces present one of the biggest risks of MRSA acquisition for patients, providing a source of direct infection to patients and of indirect infection via healthcare workers [7]. Decontaminating high-touch surfaces could prevent HAI [8]. Manual cleaning with approved disinfectants is the current standard of disinfection in most countries including the United States, and this requires supervision with constant reinforcement and education of environmental management service (EMS) staff to maintain effectiveness [9].

Surface decontamination technologies that utilize ultraviolet light or hydrogen peroxide may be effective at reducing microbial burden, possibly with greater consistency than is achieved with manual methods [10-13]. Portable pulsed xenon ultraviolet (PPX-UV) technology uses high-intensity broad-spectrum UV irradiation in the 200–320 nm range. UV breaks the molecular bonds in DNA, thereby destroying the organism and spores in laboratory settings [12,14]. Spores from Clostridium difficile (c.diff) are killed by 185–230 nm UV irradiation, overlapping the range of the PPX-UV [15].

The efficacy of PPX-UV in hospitals in comparison to manual cleaning has not been demonstrated. The purpose of this study was to compare standard manual room-cleaning to PPX-UV disinfection technology for MRSA and bacterial heterotrophic plate counts (HPC) on high-touch surfaces in patient rooms.

PPX-UV device

We used a portable PPX-UV device (Xenex Healthcare Services, San Antonio, TX) measuring 30 L × 20 W × 38 H inches (Figure 1). The device is used in empty patient rooms after discharge as prolonged exposure to UV can cause skin and eye irritation. The device used in this study housed a bulb twice as intense as in the device described by Stibich and colleagues [10], and it had new features such as a data logger, reflector, and UV pass filter. The data log recorded room number, user ID, time, date, number of pulses, amount of energy emitted and any error codes. The reflector was mounted on a column housing the xenon gas bulb emitting the pulsed UV rays. While column moved up and down during a 5-minute cycle, the reflector optimized the UV rays downward to high-touch surfaces. A UV pass filter blocked visible light while allowing UV-C to pass, making it less disturbing to the naked eyes when PPX-UV runs behind glass without curtains. UV is less effective in areas that are out of the direct line of sight; hence separate cycles for each area are recommended with 2 cycles around the patient’s bed. In a typical patient room with living room and separate bathroom, a 5-minute cycle in three different positions is recommended plus 2–3 minutes for positioning for a total of 18 minutes per room (Figure 2).

The device emitted ~450 flashes/cycle. The device requires

Figure 1 Photograph of the PPX-UV device.
positioning prior to each 5-minute cycle, so that it is necessary to have an operator in the vicinity. The device was easy to set up and operate per EMS staff operating it.

Methods
This comparative study was conducted January-February 2012 in the Central Texas Veterans Health Care System, Temple, TX with approval from its institutional review board. We are a 120-bed acute care hospital. In the facility studied, all patients undergo nasal swab at admission, transfer and discharge; these samples are tested for MRSA by polymerase chain reaction (PCR) (at admission) or culture (transfer/discharge) as a routine process of care according to institutional policy. Patients with MRSA infection either community acquired or hospital acquired are identified by culturing suspicious body site or body fluids. Individuals with MRSA detected by PCR or culture or with prior-year positive PCR/culture are placed on contact isolation during their entire hospitalization. We studied rooms vacated by patients that had a MRSA-positive PCR or culture during the current hospitalization and at least a 2-day stay.

Samples from five high-touch surfaces (bedrail, toilet seat, bathroom handrail, call button, tray table) were collected using Rodac plates, before terminal cleaning of rooms vacated by a patient on isolation for MRSA. For non-flat surfaces such as handrail, contact plates were rolled so that the entire surface was contacted. The rooms were then treated according to one of two protocols: standard manual cleaning or PPX-UV.

In the first group (manual arm; n = 10), rooms were cleaned using the standard procedures. Standard manual cleaning included cleaning visible dirt then soak and wipe cleaning with Dispatch® (The Clorox Company, Oakland, CA) disinfection solution. Dispatch® is a pre-mixed, ready-to-use 1:10 bleach solution with a contact time of 1 minute for killing bacteria. EMS personnel used cotton rags soaked in this pre-mixed solution with one to two applications and passes for all areas and surfaces in a patient room regardless of soiling. On an average, EMS personnel used 3–4 rags per room. These multiuse rags were then laundered for later use in another room. This included all the walls in bathroom and living room up to head height. EMS personnel replaced curtains if present.

In the second group (PPX-UV arm; n = 10), the room was pre-cleaned using same process described in the manual arm using Dispatch® except the focus was to clean only the visibly soiled surfaces instead of every surface in the room to achieve an aesthetic clean vs the thorough cleansing of the manual arm thus saving valuable turnaround time. Then the PPX-UV device was deployed according to manufacturer’s protocol. We then collected our post-cleaning samples ensuring that Dispatch® had completely dried of the sampling surface. Finally, the PPX-UV rooms were cleaned manually per standard protocol (similar to manual arm) to meet requirements for the healthcare facility.

Post-cleaning samples were taken from surface locations immediately adjacent to the pre-cleaning sample locations. In the PPX-UV arm the sampling took place immediately after completion of the PPX-UV cycles for the room. The Rodac sample plates were transported on icepack-lined shipping containers by overnight courier to Antimicrobial Test Laboratories (ATL), an independently contracted microbiology laboratory in nearby Round Rock, Texas. Available rooms were included if they met study criteria (MRSA-positive patient vacating;
sufficient time for shipping that day); they were randomly assigned to either manual or PPX-UV arm. In order to ensure next-day delivery, no samples were collected after the final shipper's pick-up time of 7 pm. The microbiologist at ATL was blinded to protocol arm. EMS personnel were aware of the fact that samples were being collected pre- and post-cleaning but were not aware of specific surfaces from which samples were being collected.

**Environmental testing procedure**

TSA supplemented with Lecithin and Tween 80 (neutralizes bleach) and HardyCHROM MRSA Rodac contact plates (Hardy Diagnostics, Santa Maria, CA) were received at ATL approximately 18–24 hours after sampling. All samples were given specific identification numbers prior to incubation. HPC and MRSA contact plates were incubated for 48 ± 4 hours at 30 ± 2°C and 36 ± 1°C, respectively, and individual colonies counted immediately after incubation. Every colony, regardless of color or morphology, was recorded for HPC counts. The target organism MRSA was morphologically identified (deep pink to magenta-colored colonies), and regardless of size, were recorded for MRSA counts per package insert from Hardy Diagnostics. Further MRSA colonies were then subcultured and identified using standard microbiological methods. Contact plates resulting in confluent growth were designated as too numerous to count (TNTC) for reporting purposes. TNTC and any plates with a colony count of 250 or higher for MRSA or HPC were assigned a value of 250 colonies.

**Measures and analysis**

We assessed counts of MRSA and HPC for each of 20 rooms, summing samples taken from the five different surfaces to create total MRSA and total HPC counts, respectively, for pre- and post-cleaning measures (four variables in all). Additional measures were individual surface counts, surface type, microbe type (HPC; MRSA), cleaning time in minutes, and room size in square meters. The independent variable of primary interest was cleaning protocol (manual vs PPX-UV).

Colony counts were described with means, medians and the interquartile range (q1-q3). Colony count reductions were calculated as the percent change from pre-cleaning to post-cleaning. Baseline counts were not equivalent per Wilcoxon Rank Sum test, therefore adjusting for the pre-cleaning counts was appropriate. Post-cleaning colony counts were modeled as a function of baseline count and cleaning protocol. Poisson regression is appropriate for modeling count data where the mean is equal to the variance, however, when the data are over-dispersed as these were with the variance greatly exceeding the mean, Poisson regression will under-estimate the standard errors whereas negative binomial regression produces more accurate estimates [16]. Therefore, we used negative binomial regression to estimate the association of cleaning protocol (manual vs PPX-UV) with final colony count, adjusting for baseline counts. The strength of association between predictor and outcome is reported as a regression coefficient for change in the log of counts when the factor is present, and can be exponentiated as an incident rate ratio with 95% confidence interval (IRR, CI95). The IRR is similar to the more familiar odds ratio where a significant effect is one whose CI95 excludes 1. The IRR is the factor by which the expected colony count is multiplied per 1-unit increase in the predictor. For the cleaning protocol, the predictor was either 0 (PPX-UV) or 1 (manual cleaning).

**Results**

Colony counts in 20 rooms (10 per arm) prior to cleaning varied by cleaning protocol: for HPC, manual (mean = 255, median = 278, q1-q3 132–304) vs PPX-UV (mean = 449, median = 365, q1-q3 332–530), and for MRSA, manual (mean = 127; median = 28.5; q1-q3 8–143) vs PPX-UV (mean = 108; median = 123; q1-q3 14–183). These baseline plate counts were not equivalent and were not normally distributed. After cleaning, the counts averaged 60 colonies (76% reduction; manual) vs 8 colonies (98% reduction; PPX-UV) for HPC, and 11 colonies (91% reduction; manual) vs 1 colony (99% reduction) for MRSA. The HPC count was significantly greater for the manual cleaning arm relative to the PPX-UV arm, adjusting for baseline total HPC counts in the rooms (IRR = 12.9, CI95 3.5–47.8, p < .01), meaning the expected count was multiplied by a factor of 13 when the independent variable increased by one unit from 0 (machine) to 1 (manual). Similarly, the MRSA count was significantly higher in the manual cleaning arm relative to the PPX-UV arm (IRR = 7.2, CI95 1.3–41.4, p < .03). See Tables 1, 2 and 3. The majority of the difference in post-cleaning colonies was due to high residual counts on the toilet seats in the manual arm. The number of MRSA-positive sites per room after manual cleaning was 0 (4 rooms), 1 (4 rooms), or 2 (2 rooms), and the number of MRSA-positive sites per room after PX-UV cleaning was 0 (7 rooms), 1 (2 rooms), or 2 (1 room). The average number of minutes spent cleaning a room was 49 minutes including device time (SD = 13) for PPX-UV and 63 minutes (SD = 29) for manual cleaning (t-statistic = 1.5; df = 12.1; p = .17, n.s.). The average size of a patient room (living & bathroom) in the manual arm was 23 m² and in the PPX-UV arm was 25 m².

**Discussion**

Our study showed that a “no-touch” semi-automated system, the PPX-UV, was effective in substantially
reducing the heterotrophic bacterial and MRSA burden on high-touch surfaces in rooms vacated by MRSA-positive patients. PPX-UV disinfection may add to the armamentarium against HAI's without risking the adaptive genetic resistance incurred by pharmaceutical weapons. Implementation including training EMS personnel to operate the device was minimal, and time spent cleaning was not increased. Because there were separate cycles for bathroom and living room, the surface reduction in aerobic colony counts may be better than with other UV systems; a head-to-head comparison of UV area disinfection devices may be warranted [12,13].

Consistency in patient room-cleaning is needed. High residual colony counts were observed on the toilet seats post-cleaning in the manual arm. This may be due to human inconsistency or memory failure regarding which parts of the room have been cleaned, a common problem with repetitive tasks. A highly structured approach that involves educational, procedural, and administrative interventions with repeated performance feedback to EMS by monitoring the thoroughness of cleaning with either adenosine 5'-triphosphate (ATP) assays or fluorescent dyes has been shown to be successful in reduction of microbial contaminants in patient rooms [17,18]. Other intervention programs such as monitoring room cleanliness using checklists may also result in significant improvement in cleaning practices [19]. Although such interventions improve cleaning, in the post-intervention period the increase is no more than 85% [20], and the effects may decrease post-intervention unless ongoing feedback to environmental services staff is sustained [9]. Thus empowering EMS with a "no touch" semi-automated system such as PPX-UV to substantially reduce the microbial burden on high-touch surfaces, combined with education and feedback, may help us achieve the desired effect of thorough disinfection for every vacated patient room. Training on the device was simple; EMS personnel commented they could easily incorporate this system into their routine cleaning practices. The usual run time of PPX-UV was 15 minutes and required 2–3 minutes of additional setup time. Hence the authors believe PPX-UV disinfection could be integrated into routine hospital cleaning operations without disruption of patient flow or undue burden on EMS staff.

Our study adds to the existing debate in literature about one long cycle vs several shorter cycles for UV disinfection and about a UV device's effect on aerobic surface colony count reduction. Since separate cycles are needed for bathroom and two positions for living room, the surface reduction in aerobic colony counts was similar to studies of other UV systems that had separate

### Table 1 Methicillin-resistant *Staphylococcus aureus* and bacterial heterotrophic plate counts before and after disinfection per room for five high-touch surfaces total

<table>
<thead>
<tr>
<th>Colony count measures of central tendency and variability by room mean; median (IQR)</th>
<th>Before</th>
<th>After</th>
<th>Reduction</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>HPC</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Manual arm</td>
<td>255.0; 278.0 (132-304)</td>
<td>60.4; 31.0 (15-70)</td>
<td>76.3%</td>
</tr>
<tr>
<td>PPX-UV arm</td>
<td>449.0; 364.5 (332-530)</td>
<td>8.4; 4.0 (1-10)</td>
<td>98.1%</td>
</tr>
<tr>
<td><strong>MRSA</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Manual arm</td>
<td>127.3; 28.5 (8-143)</td>
<td>11.3; 1.0 (0-4)</td>
<td>91.1%</td>
</tr>
<tr>
<td>PPX-UV arm</td>
<td>108.2; 123.0 (14-183)</td>
<td>0.7; 0.0 (0-1)</td>
<td>99.4%</td>
</tr>
</tbody>
</table>

HPC: Bacterial heterotrophic plate counts.  
MRSA: Methicillin-resistant *Staphylococcus aureus*.  
PPX-UV: Portable pulsed xenon ultraviolet.
bathroom cycles and perhaps better surface reduction as compared to studies with no separate bathroom cycles [11-13]. In the PPX-UV arm, the focus was to get the rooms aesthetically clean by manually wiping all grossly soiled surfaces. We believed that our efforts to focus on the aesthetic cleaning, thus allowing for a truncated pre-cleaning routine is consistent with new published literature. Anderson et al. showed that despite lack of pre-cleaning there was statistically significant reduction in organisms such as VRE and C.diff spores [21]. Zhang et al. also showed that the organic material from the hospital rooms only modestly affected UV killing of spores [22]. The above research findings could explain why PPX-UV arm had lower counts inspite of a truncated pre-cleaning routine. The manufacturer recommended the same cycle times for patient rooms with c. diff spores based on preliminary lab data, and studies are underway at another site to examine the efficacy on c. diff spores in a hospital setting, however, future independent research should directly assess sporicidal capacity of the PPX-UV. Federally funded multi-site comparative study with multiple microbial targets is currently underway. Future research should also assess patient outcomes and cost-effectiveness for major and emergent infectious agents in healthcare systems with and without systematic PPX-UV cleaning.

Our study has several limitations: it was not designed to assess impact on the actual transmission of healthcare-acquired infections. The number of surfaces and rooms sampled was small but similar in size to previously published studies [11,12]. The protocol did not evaluate the incremental impact of UVC treatment following routine cleaning, a process to be evaluated in our next study. The delay to culture introduced by the overnight transport process may have influenced culture viability, however, both manual and PPX-UV samples experienced the same transport periods thus reducing likelihood of bias from this source of variability. EMS personnel were not blinded to the study nor to the protocol to be used in each room. Supervisors commented that they were taking longer than usual to clean the rooms, suggesting increased vigilance; this would potentially bias our results toward the null. Better differential effects might be achieved in a real-world implementation where lapses in EMS attentiveness may occur unpredictably. The rather high post-cleaning MRSA counts in the manual cleaning arm may be due to lack of actual manual cleaning process rather than the lack of efficacy of the manual cleaning process. While it is possible that ours is the only facility in the VA system whose cleaning crew has inconsistency in cleaning thoroughness, we suspect it is more a part of the human condition. Two multisite trials that we know of are currently in progress and should provide larger scale results on PPX-UV effectiveness.

### Conclusions

In conclusion, PPX-UV technology appears to be superior to manual cleaning alone for MRSA and HPC. We believe incorporating 15 minutes of PPX-UV exposure time to current hospital room cleaning practice can improve the overall cleanliness of patient rooms with respect to selected micro-organisms by a factor of 7–12 in a sustainable manner. Outcome studies are being conducted to assess the economic and clinical impact of this technology.

### Competing interests

This study’s laboratory activity including use of the PPX-UV machine was supported by a grant from Xenex Healthcare Services, LLC. No author has identified a competing interest regarding the study beyond working for the institution studied (Department of Veterans Affairs, Veterans Health Administration).
Authors’ contributions
All authors made a significant contribution to the project. CJ and RQ developed the methodology, protocol, performed data collection and manuscript preparation. TH and JW carried out the microbiology and contributed to the manuscript. JZ and LC participated in statistical analysis and contributed to the manuscript. All authors read and approved the final manuscript.

Acknowledgements
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Funding
This study’s laboratory activity including use of the PPX-UV machine was supported by a grant from Xenex Healthcare Services, LLC.

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Abstracts published at Infection Prevention 2014, Glasgow

Forward

This Journal of Infection Prevention supplement contains the abstracts published at the Infection Prevention 2014 Conference in Glasgow, Scotland. The submitted abstracts represent an important part of the Conference, and we would like to congratulate all those who have had their abstracts accepted and extend our gratitude to all who submitted an abstract. Each abstract undergoes a blinded peer review process and is assigned a score. Those abstracts with a sufficiently high score are accepted for publication at the conference and a small proportion of those have been selected as oral presentations, the remainder as posters. We hope that you find this abstract supplement a useful resource.

The Infection Prevention Society Scientific Programme Committee (Jonathan Otter, Christina Bradley, Michael Nevill, Karen Wares, Elaine Ross, Philip Pugh and Pat Cattini)

Oral Presentations

Abstract ID: 2906

Peri-anal screening for *Clostridium difficile* - is it the way forward?

Marietta Niala, Rohinton Mulla, Anne George

Luton and Dunstable University Hospital

Introduction

*Clostridium difficile* is a gram positive bacterium that can live harmlessly in the gut of some people. However, if the balance of the normal flora becomes disturbed *C. difficile* can proliferate and cause infection such as diarrhoea, abdominal pain, loss of appetite etc. In 2006, the Trust had a total of 351 *C. difficile* cases (community and hospital acquired). The Trust is aiming to achieve zero *C. difficile* infections. In December of 2013, active *C. difficile* screening of adult patients on admission (emergency and elective) was implemented.

Methods

A peri-anal swab was used to determine how many of the patients on admission were *C. difficile* carriers. Swabs were plated on to a Biomerieux Chrom ID *C. difficile* agar plate and suspected colonies were confirmed using the Alere Techlab *C. difficile* Quik Chek Complete test.

Results

A total of 1888 peri-anal samples were tested and 43 (2.3%) were found to be *C. difficile* positive. This includes all elective and emergency admissions in all adult specialties. 24 (56%) out of the 43 positive samples were found to be toxigenic. Four out of the 43 peri-anal *C. difficile* positive patients turned out to be *C. difficile* toxin positive following a stool sample.

Discussion

Peri-anal swabs can be used to successfully screen *C. difficile* carriers. These patients may be at risk of getting *C. difficile* infections following courses of antibiotics and are likely to spread infections in susceptible contacts. Currently, *C. difficile* carriers identified during the study are not isolated. Alternatively, it may be postulated that asymptomatic carriage may reflect immunity to *C. difficile* infections. We also plan to study the effect of isolating asymptomatic carriers in the spread of *C. difficile* disease. All positive isolates will be sent for typing to determine any relevance.

Abstract ID: 2988

Time from first exposure to detection for carbapenemase-producing Enterobacteriaceae (CPE)

Andrea Ledgerton, David Harvey

Wirral University Teaching Hospital NHS Foundation Trust

Introduction

Our hospital experienced two CPE outbreaks between 2011 and 2013. A clonal *Klebsiella pneumoniae* VIM-4 outbreak was followed by an OXA-48 outbreak. To inform our strategy on duration of screening, conversion time was assessed during two outbreaks of CPE.

Methods

Rectal screening of contacts was undertaken weekly until 4 weeks after the last patient was discharged. Time lines of all cases were constructed. For cases with clear epidemiological links to a known case, likely time from first exposure to CPE detection was calculated.

Results

25 patients were identified (14 VIM-4, 11 OXA-48). The mean conversion time was 26 days, with a range of 4 to 85 days. Comparing VIM-4 with OXA-48, the mean was 23 days vs 31 days. Overall, 70% of cases were identified by 4 weeks, 90% by 6 weeks and 100% by 13 weeks.

Discussion

In order to detect CPE transmission, four weeks screening from first exposure should be considered the minimum necessary. Extending this to six weeks would capture most cases. Three months screening would detect primary contacts requiring longer to convert and potentially would cover two standard incubation periods, so uncovering secondary contacts. As part of a multifaceted approach of early detection and containment, prolonged active surveillance should be considered as a standard measure. Screening should continue for a sufficient time period after the last known patient is discharged. Based on these data, six weeks would be pragmatic, and three months optimal.
Abstract ID: 2881

Assessing the burden of carbapenemase-producing organisms from inter-hospital patient transfers and from patients receiving healthcare abroad

Janice Scott, Damien Mack
Royal Free London NHS Foundation Trust

Carbapenem resistance is emerging within UK healthcare facilities, predominantly from healthcare facilities abroad. There is debate about admission screening for carbapenemase-producing organisms (CPOs) as a detection tool, to aid early containment and plan preventative measures. The trust became a pilot site for the proposed national Public Health England (PHE) CPO Toolkit, later published December 2013.

Aims and methods
A point prevalence survey (PPS) was undertaken across all Trust wards. Patient inclusion and exclusion criteria were adopted as per PHE. The case definition was designed for clarity and generalizability. All inpatients were asked if they had healthcare abroad or healthcare in a UK hospital in the past 12 months, or contact with a CPO. This information was then used to assess the burden.

Results
Of 551 patients surveyed, 2% (11) had received healthcare abroad and 20.3% (112) within the UK, within the last 12 months, and 17.4% (96) had healthcare in a London hospital, subsequently identified as a high-risk group.

Of the high-risk group, 3.4% (19) of patients in high-risk areas such as critical care were screened on admission before the survey, none within general wards.

The high-risk areas with more than 20% of suspected cases are the stroke unit, renal unit, private patient unit, hepatobiliary and transplant wards, intensive care unit, oncology ward and infectious diseases ward.

The gold standard approach outlined in the toolkit indicated that all patients who were high risk and being admitted through the Trust should be screened and isolated. On balance, patient safety considerations indicate the need for a pragmatic approach, which is to predominantly screen and isolate only the patients in the highest risk categories on admission.

Discussion
We are sharing the PPS survey tool with other London trusts, to identify trends regionally and to compare teaching trusts to district general trusts.

Abstract ID: 2884

Where's all the VRE gone? - A successful VRE bundle at a Singapore hospital

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1National University Hospital, Singapore. 2Saw Swee Hock School of Public Health, National University Singapore

Introduction
Vancomycin-resistant enterococci (VRE) emerged at our hospital in the mid-2000s. Despite implementing targeted active surveillance in 2006, the prevalence of VRE continued to rise. Further interventions were introduced in late-2012 / early-2013.

Methods
Our VRE bundle comprised: monthly cleaning audit of 10% of general discharge using fluorescent markers, enhanced precautions signage, a minor expansion of active surveillance, implementation of hydrogen peroxide vapour (HPV) for terminal disinfection following the discharge of VRE patients, a change in the bleach cleaning solution, and an automated electronic alert system to identify known VRE carriers at the time of admission. In addition, education and feedback to staff of MDRO rates were provided regularly in various hospital forums. Monthly cases of VRE infection and colonization from January 2008 to January 2014 were extracted from hospital records. A ‘breakpoint’ regression model was fitted to the monthly number of VRE cases. The model evaluates potentially differing trends before and after a breakpoint, which is estimated by the model instead of being specified a priori, resulting in less potential for bias.

Results
A total of 341 cases were reported over this 73 month period. The best estimate for the breakpoint corresponds to early February 2013 (95% confidence interval, CI: August 2012—June 2013), when the bundle was implemented. The peak incidence was 9.2 cases per month (95% CI: 6.0—13.2) in March 2013 and reduced to 2.4 cases per month (95% CI: 1.1—4.7) by January 2014.

Discussion
The bundle of interventions was associated with a significant change in the incidence of VRE at our hospital. Confidence intervals around the breakpoint suggested that all elements of the bundle (apart from the change in the bleach cleaning solution) could have played a role in the reduction of VRE.

Abstract ID: 2826

‘Don’t Go Breaking My Heart’! Benchmarking practice in response to elevated cardiac surgery infection rates

Martin Still, Nichola Baker
Brighton & Sussex University Hospitals NHS Trust

Improvement Issue and Context
The Trust submits cardiothoracic surgical site infection (SSI) data to Public Health England that is also fed back to the surgeons. In the first quarter of 2013 the infection rate was 12.9 % (95% CI 6.1 – 19.7) compared to a national average of 5.2% (95% CI 4.9 – 5.3, p=0.001). This prompted an immediate investigation into aspects of pre, peri and post-operative practices, benchmarking against the NICE SSI Clinical Guideline and networking with other organisations that undertook cardiothoracic surgery.

Methods and Measurement
Infection Control (IC) practices come as a ‘bundle’ so it can be difficult to isolate the actual cause and effect of any one intervention. The IC team focused on standards stated in the NICE SSI Guideline that included hand hygiene and personal protective equipment practices across the unit. The Royal Brompton & Harefield Trust hosted a networking meeting where best practices were shared. Engagement with the surgical team was initially a challenge. All information was shared at the time it was gathered that prompted discussion. Observations of practice were fed back immediately in order to effect maximum change. Work started to change types of dressings used and what information was given to patients. Work also started on improving the patient hygiene process. There was resistance to change, probably because some of the practice changes were imposed and sustaining change required leadership.

Evidence of Improvement
The Trust submits cardiothoracic surgical site infection (SSI) data to Public Health England that is also fed back to the surgeons. In the first quarter of 2013 the infection rate was 12.9 % (95% CI 6.1 – 19.7) compared to a national average of 5.2% (95% CI 4.9 – 5.3, p=0.001) against a national average of 5.3% (CI 5.5–6%) and compliance with hand hygiene and personal protective use increased.

Future Steps
At the networking meeting it was agreed that a national cardiac surgery networking group would be set up and meet around the country to discuss and continue to share best practices.

Abstract ID: 2905

Antimicrobial Prescribing: What do we do badly and how can we improve?

Naina McCann1, Leah Owen2, Micheal Sagmeister3, Ryan Wong4, Dimple Shah5, Oliver Turner6, Anita Choraria7
1Watford Hospital. 2Watford General Hospital. 3North Middlesex Hospital. 4Barnet Hospital. 5Royal Free Hospital. 6Basildon Hospital
Improvement Issue and Context
The aim of the audit was to evaluate antimicrobial prescribing on the wards of a large teaching hospital, to highlight areas of poor compliance and to devise a targeted, sustainable and realistic intervention to improve practice.

Antimicrobials are very commonly prescribed medications in hospitals. Standardising the approach to prescribing has been successful in reducing cost associated with antimicrobial use and reducing the prevalence of resistance phenotypes associated with increased mortality.

Methods and Measurement
A group of seven foundation year doctors designed a proforma to collect data on different aspects of antibiotic prescribing within our hospital to see how well local protocol was adhered to. Adult inpatients were audited and the initial data was collected over a one month period gaining a sample size of 75.

Evidence of Improvement
Initial results highlighted that the areas of poor compliance when prescribing antimicrobials were: stating duration of antimicrobial course in the notes (36% compliance), and documentation on the drug chart recommending stop date for antimicrobials (26%).

A targeted intervention of a specific sticker to place on the drug chart when antimicrobials are prescribed was introduced and trialled on two wards. When re-audited one month post-intervention it was found that use of the sticker improved prescribing practice. For example post-intervention, 76% of prescriptions stated a stop date for antimicrobials.

Future Steps
The implementation of a specific sticker on the drug chart for antimicrobial prescribing has been shown to improve antimicrobial prescribing within this hospital. From this, an assumption can be made that it reduced unnecessary antimicrobial doses, in particular from the stopping of antimicrobials on the correct stop date. It is therefore recommended that the sticker be rolled out onto other wards with the aim in the future of incorporation into the drug chart.

Abstract ID: 2958
Reduction of the number of missed isolation days in the Alder Hey High Dependency Unit using the Bioquell Pod

Josephine Keward1, Pauline Bradshaw1, Jonathan Otter2
1Alder Hey Children’s NHS Foundation Trust. 2Bioquell

Introduction
Single rooms are in short supply in many NHS hospitals. Our 15 bed high dependency unit (HDU) has four side rooms and a frequent need to isolate bacterial (MRSA, ESBL and CRE) and respiratory (RSV and influenza) pathogens. Side rooms are often occupied by patients with infectious and non-infectious needs, meaning that ‘isolation’ is attempted in the bays. Bioquell Pods are semi-permanent structures that are used to convert multi-occupancy bays into single-occupancy pods.

Methods
Three Pods were implemented in February 2013. Bed usage was recorded each day. The number of missed isolation days was compared for the year prior to the Pods (Feb 2012 – Jan 2013) vs. the first year of Pod use (Feb 2013 – Jan 2014). Patient isolation priorities were as follows: airborne (e.g. measles) > droplet (e.g. respiratory virus) > contact (e.g. MRSA, rotavirus). The percentage of ‘missed isolations’ was calculated for each pathogen (when a patient requiring a side room was placed in a bay), and compared using the Chi squared test.

Results
Data were recorded for 203 days pre-Pod and 211 days in the first year of pod usage. Missed isolation days fell from 58% (662/1138) pre-Pod to 15% (80/532) during the first year of pod use (p<0.001) (Table). The impact was most marked for MRSA (51% to 8%, p<0.001) and respiratory viruses (60% to 16%, p<0.001).

Discussion
Introducing Pods to our 15 bed HDU significantly reduced missed isolation, and thus transmission risk. The effect was especially marked for MRSA and respiratory viruses.

Conflict of Interest
Jon Otter works part-time for Bioquell.

Abstract ID: 2912
Enhanced surveillance of E. coli bacteraemia in Scotland - A pilot study

Donald Bunyan, Julie Wilson, Samantha Fleming, David Henderson, Camilla Wiuff, Alistair Leanord
Health Protection Scotland

Introduction
The number of E. coli bacteraemia reported in Scotland has increased continuously since 2009. The recent Scottish Point Prevalence Survey (PPS) identified that among the HAIs, the proportion of cases attributed to E. coli was higher in 2011 (12.1%) than in 2005/6 (3.1%).

This pilot study aimed to measure the burden of disease and identifying ways to describe the epidemiology and primary causes of E. coli bacteraemia in Scotland.

Methods
An enhanced E. coli dataset was collected by eight participating NHS boards within a 3-month data collection period (October to December 2013).

Results
Of the 532 cases obtained, nearly 60% of cases were classed as inpatients. When assessing previous hospital admissions, 30% were admitted to hospital in the month prior to developing a bacteraemia. More than 50% of cases had a urinary tract infection as the primary cause of infection (i.e. the infection that is thought to have caused the bacteraemia). Nearly 50% had developed bacteraemia following a primary infection acquired in the community. When asked as to whether the potential primary cause of the bacteraemia was medical procedure related / device related or if there was another cause, less than 10% of the bacteraemia were found to be device related, although for the majority this information was unknown.

Discussion
This pilot study has highlighted population characteristics that are associated with patients in NHS Scotland who have bacteraemia caused by E. coli. It has provided a basis with which to start to generate hypotheses for targeting interventions in healthcare settings, with the addition of other linked datasets to elucidate more complex population characteristics including health outcome. Future work will be required to demonstrate and quantify the effectiveness of these interventions in different care settings.

<table>
<thead>
<tr>
<th>Pathogen</th>
<th>Pre-Pod use (%)</th>
<th>During Pod use (%)</th>
<th>p value</th>
</tr>
</thead>
<tbody>
<tr>
<td>MRSA</td>
<td>51.3</td>
<td>8.0</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>ESBL / CRE</td>
<td>26.4</td>
<td>15.7</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Respiratory viruses</td>
<td>60.3</td>
<td>16.3</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Rotavirus</td>
<td>49.3</td>
<td>60.8</td>
<td>0.109</td>
</tr>
<tr>
<td>Overall</td>
<td>58.2</td>
<td>14.8</td>
<td>&lt;0.001</td>
</tr>
</tbody>
</table>

Table. Missed isolation in the first year of Bioquell Pod use compared with the previous year
Abstract ID: 2968

First UK trial of Xenex PX-UV room decontamination device

Angela Beal, Karren Staniforth, Nik Mahida, Natalie Vaughan, Mitch Clarke, Tim Boswell
Nottingham University Hospitals NHS Trust

Introduction
There is increasing recognition of the role of the healthcare environment as a reservoir for key pathogens, such as vancomycin-resistant enterococci (VRE). New automated environmental decontamination technologies utilising hydrogen peroxide and ultraviolet-C light (UVC) have been developed, which may have improved efficacy compared with manual disinfection.

The purpose of this study was to evaluate the efficacy of a pulsed xenon UV room disinfection device (PX-UV) in a centre for clinical haematology, which is at high risk for VRE.

Method
Two sampling methods were used to evaluate the device. i) Tryptone soya agar (TSA) contact plates for total surface aerobic colony count pre clean, post clean and post exposure to PX-UV. ii) Sponge recovery with broth enrichment to provide a sensitive presence/absence test for VRE post clean and post exposure to PX-UV. Ten rooms were sampled with contact plates and eight additional rooms sampled with sponge recovery. The total colonies on the TSA plates were enumerated after 48 hours incubation. Identification of VRE was established by standard laboratory methods.

Results
Median total aerobic counts pre-clean, post manual cleaning and post PX-UV were 35.5, 4 and 2 CFU respectively. Of the 160 samples taken post manual cleaning, 26 (16%) were positive for VRE. However after deployment of PX-UV, VRE was still recovered from 16 of 160 matched samples (10%).

Conclusion
The Xenex PX-UV system produced a greater reduction in total surface contamination compared to standard manual cleaning alone. However, it did not completely eradicate VRE from the environment. User feedback was positive and the increase in time taken to complete a room was 20 minutes meaning this technology could be used as an adjunct to a manual cleaning process with minimal increase in overall time taken.

Conflict of Interest
Xenex provided a free loan of the PX-UV device for the duration of the study and provided funding for a member of the research team to attend conference last year.

Abstract ID: 2865

Hepatitis A and E virus seropositivity amongst healthy young adults in India: Implications for immunisation & public health policy

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1Army College of Medical Sciences, India 2 Armed Forces Medical College, India

Introduction
Various serosurveys and studies provide ample evidence of differing perspectives regarding epidemiology of hepatitis A virus (HAV) and hepatitis E virus (HEV) in India and other developing countries. This study was conducted to assess seroprevalence of HAV and HEV and its associated factors with an aim to provide inputs to planners regarding the requirement for the HAV vaccine. The proportion of new HAV and HEV positives among patients admitted to tertiary healthcare facilities was also assessed.

Methods
A multi-centre cross sectional survey amongst 4175 healthy young adults was carried out in training centres, selected by multistage random sampling, giving equal representation to all regions of India. Sample size was calculated by taking prevalence of HAV seropositivity amongst adults as 60% and alpha 5%. A total of 695 patients were also evaluated in four selected hospitals.

Results
Seroprevalence for HAV and HEV was 92.68% (95% CI. 88.92, 89.37) and 17.05% (15.90, 18.26), respectively. Bivariate analysis found statistically significant association (p<0.05) between HAV and HEV seropositivity with various factors. Logistic regression showed that hand washing without soap, regular close contact with domestic animals, consumption of unpasteurized milk and regular consumption of food outside home were risk factors for HAV (p<0.05). For HEV, irregular hand washing, consumption of unpasteurized milk and irregular consumption of freshly prepared food were risk factors (p < 0.05). Among patients, the distribution of HAV, HEV, hepatitis B surface antigen (HBsAg) and HCV was 10.22%, 21.87%, 16.98% and 3.74%, respectively.

Discussion
A high natural immunity against HAV among the healthy young adults clearly demonstrates that vaccination against HAV is not required at present. The large proportion being susceptible to HEV points towards the requirement of preventive strategies in the form of safe drinking water supply and sanitation, increasing awareness through information, education and counselling, and behaviour change with respect to personal hygiene especially hand and food hygiene.

Abstract ID: 2913

Improvements in pain, odour, sleep and social activities for patients with chronic wounds using novel aqueous oxygen peroxide (AOP) technology

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Introduction
Chronic venous leg ulcers (VLUs) are a common cause of morbidity in community settings. Patients with VLUs often experience pain, odour, sleep interruption and reduced participation in social activities. We evaluated the impact of applying aqueous oxygen peroxide (AOP) on the quality of life for patients with VLUs.

Methods
We performed a primary care based, double-blind, randomised, placebo-controlled trial (RCT) and a small follow-on evaluation. 61 patients suffering with chronic, static, venous leg ulceration were included in the RCT, and randomised to two weeks of treatment with 20 parts per million AOP or sterile water placebo. Four patients were enrolled in the follow-on evaluation designed to explore the impact on patients’ quality of life in more detail; all patients in this evaluation were treated with AOP. RCT patients scored pain before and after each treatment to two weeks of treatment with 20 parts per million AOP or sterile water placebo. Patients treated with AOP experienced greater reductions in ulcer pain after treatment compared with placebo treatment (mean reduction 28.4 vs. 9.6, p=0.001). In the follow-on evaluation, average pain (6.0 vs. 3.5), odour (5.0 vs. 0.0), impact on sleep (4.3 vs. 0.8), and impact on social activities (5.8 vs. 3.3) were all reduced (composite quality of life average 5.2 vs. 1.9, p=0.001).

Discussion
The use of AOP in general practice produced reductions in ulcer pain and wound odour, which is likely to be linked to the antimicrobial properties of AOP. We also recorded improvements in sleep and participation in social activities for patients treated using AOP. Treatment of chronic VLUs in general practice using AOP confers substantial benefits to a patient’s quality of life.
Conflict of Interest
Jon Otter works part-time for Bioquell; Nick Adams and John Chewins are employed by Bioquell.

Abstract ID: 2983

Service user involvement: How well are we doing?
Andrea Whitfield
Richard Wells Research Centre, University of West London

Introduction
The Service User Research Forum (SURF) was set up by the HCAI Research Network in 2007 to establish patient and public involvement (PPI) in HCAI and Anti-microbial Resistance (AMR) research. SURF members work alongside research teams to provide lay input into research priorities, design data collection tools, comment on funding applications, and in some cases become co-applicants. The HCAI Research Network investigated how PPI is integrated into HCAI and AMR research; the challenges and benefits perceived by researchers and how researchers can be further supported to integrate PPI.

Methods
An online survey using a mix of multiple choice and open-ended questions was sent to 500 researchers who had published in the Journal of Infection Prevention and Journal of Hospital Infection or who had worked with SURF in the past. Multiple choice data was analysed in SPSS. Open-ended responses were analysed thematically.

Results
Eighty responses were received. Of those who had carried out research between 2011-2013, 51% (n=34) had included PPI and 87% (n=46) believed PPI could benefit research. Methods of involving the public varied considerably, the most common contribution of lay individuals being to review research priorities, data collection tools and documents for research participants. Examples of the benefits of involvement were a greater understanding of the patient perspective and more accessible patient materials. For those not involving the public (n=33) the main barriers were lack of time and access to lay individuals.

Discussion
Public involvement is not as widely integrated into HCAI and AMR research as some other health disciplines. However, there are examples of where it is adding value to research in the field. To maximise the benefits of PPI, the research community should include lay individuals as partners in research as opposed to a sounding board for researcher generated ideas and materials.

Abstract ID: 2878

What’s happened to a belief about ‘duty of care’ in hand hygiene?
Sharon Salmon, Mary-Louise McLaws
UNSW Medicine, The University of New South Wales, Australia

Introduction
It is accepted by hospital clinical governance and infection control experts that every clinician’s duty of care includes hand hygiene yet healthcare workers globally continue to struggle with compliance. To explore whether hand hygiene is viewed by clinicians as their duty of care we conducted focus groups discussions with clinician staff in Vietnam.

Methods
We conducted 10 focus group discussions with nursing and medical staff from five large public hospitals across Hanoi, Vietnam. A locally trained researcher facilitated all discussions. Tape recordings were transcribed verbatim and then translated into English. Thematic analysis was conducted by two investigators.

Results
Expressed frustration with high workload, limited access to hand hygiene solutions, and hand hygiene guidelines being too difficult to recall were accepted as bona fide reasons for non-compliance. No participants acknowledged or expressed hand hygiene as being a ‘duty of care’ to their patients. A dominant justification for non-compliance was the lack of hand hygiene among visitors and family members who provide daily basic care to patients. Although ‘duty of care’ for patients was absent there was a strong duty of care to ones-self about when hand hygiene was a benefit to their own health regardless of patient load or environmental challenges.

Discussion
Vietnam has unique barriers to compliance that includes limited access to alcohol based hand rub, clean running water, soap and hand towels. These barriers are amplified by overcrowded conditions and dual bed occupancy. Clinicians require assistance with the interpretation and importance of the ‘My 5 Moments for Hand Hygiene’ – commencing with an emphasis on a ‘duty of care’ to their patient regardless of compliance by visitors and family. Remodelling training to focus on ‘duty of care’ commencing with before and after patient contact (Moments 1& 4) may assist with improving hand hygiene compliance.
Abstract ID: 2814

**Doripenem may be an alternative antibiotic to treat imipenem and meropenem-resistant Enterobacter cloacae infections**

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Committee of Infection Control, Tainan Municipal Hospital, Tainan, Taiwan

**Introduction**

The therapeutic options for imipenem and meropenem-resistant Enterobacter cloacae infections are usually limited due to co-resistance to other classes of antibiotics. In this study, we attempted to explore whether doripenem, a newer carbapenem, can be prescribed to treat these infections.

**Methods**

At a regional hospital in southern Taiwan, since 2010, 16 isolates of E. cloacae showing simultaneous resistance to both imipenem and meropenem were collected and analyzed. E-test strips were used to detect the minimum inhibitory concentrations (MICs). The tested carbapenems were imipenem, meropenem, and doripenem. Interpretation was according to the Clinical and Laboratory Standards Institute guideline published in 2014.

**Results**

All isolates were non-susceptible to imipenem and meropenem with MICs ≥ 2 mg/L. By contrast, various doripenem MICs were observed: 1 mg/L, 5, 31.3%; 2 mg/L, 9, 56.3%; 4 mg/L, 1, 6.3%; and > 32 mg/L, 1, 6.3%.

**Discussion**

In this study, 31.3% (5 of 16) of imipenem/meropenem-resistant E. cloacae isolates were susceptible to doripenem, indicating that doripenem may serve as an alternative choice to treat such infections. Previous pharmacodynamic studies suggested that infections caused by organisms with doripenem MICs 4 mg/L may be cured by the recommended dose of doripenem (500 mg administered over four hours every eight hours). Accordingly, up to 93.7% (15 of 16) of the isolates may be sufficiently treated with doripenem. Therefore, when imipenem/meropenem-resistant E. cloacae infections are encountered, doripenem susceptibility is worthy of being tested. If the etiologic agent remains susceptible to doripenem, or even with MICs up to 4 mg/L, the antibiotic may be feasible to treat the infections.

Abstract ID: 2820

**Flomoxef may be prescribed as the first-line antibiotic to treat acute pyelonephritis caused by extended-spectrum beta-lactamase-producing organisms**

Chin-Lu Chang
Committee of Infection Control, Tainan Municipal Hospital, Tainan, Taiwan

**Introduction**

Carbapenems are usually recommended to treat infections caused by extended-spectrum beta-lactamase (ESBL)-producing organisms. However, frequent use of carbapenems may predispose to the increase of carbapenem-resistant organisms, which are growing worldwide. The present study was conducted to explore whether flomoxef, a cephamycin with activity against ESBL-producing organisms, can be substituted for carbapenems to treat acute pyelonephritis (APN) caused by ESBL-producing organisms in order to reduce carbapenem use.

**Methods**

From May 2012 to April 2014, patients with APN caused by ESBL-producing organisms and treated with flomoxef were enrolled as cases. Patients with similar infections but treated with doripenem were enrolled as controls for comparison. Treatment success was defined as fever and other systemic signs or symptoms gradually subsided within three days of antibiotic administration. Otherwise, it was defined as a treatment failure.

**Results**

A total of 20 cases and 30 controls were retrospectively identified during the two-year study period. Escherichia coli was found in 46 patients, and the remaining 4 were caused by Klebsiella pneumoniae. Treatment success was found in 18 of the 20 cases with flomoxef therapy; the two failure cases were subsequently treated successfully with doripenem. All the 30 controls with doripenem therapy achieved successful treatment results. The rates of treatment success were not statistically significant between the two groups.

**Discussion**

In this study, flomoxef was found to achieve a high rate (18 of 20, 90%) of treatment success for APN caused by ESBL-producing organisms; hence, we recommend that flomoxef may be prescribed as the first-line antibiotic to treat such infections, especially mild to moderate infections. If treatment failure by flomoxef occurs, the subsequent use of carbapenems as the salvage antibiotic is still adequate. Consequently, if this measure become a part of the antimicrobial stewardship programs, the reduction of carbapenem-resistant organisms may be anticipated by reducing carbapenem use.

Abstract ID: 2833

**An increasing incidence of extended-spectrum beta-lactamase-producing strains in Escherichia coli bacteremia**

Chao-Tai Lee, Shiu-Yi Lu, Chin-Lu Chang, Pi-Wen Chen
Tainan Municipal Hospital, Tainan, Taiwan

**Introduction**

Extended-spectrum beta-lactamase (ESBL)-producing organisms are increasing worldwide, which most frequently occurs in Escherichia coli now. This study was to explore an increased extent of the incidence of ESBL-producing strains in E. coli isolated from blood at a regional hospital, which provides important information for empiric antibiotic therapy.

**Methods**

This was a retrospective study at a regional hospital in southern Taiwan. From 2009 to 2013, all E. coli isolates obtained from blood cultures were enrolled in this study. If multiple isolates were identified from the same patient during the same hospitalization period, only the first isolate was enrolled. ESBL-producing strains were confirmed by double disk diffusion test.

**Results**

A total of 2083 E. coli isolates were enrolled. The ESBL-producing strains accounted for 7.5% (31 of 381), 8.3% (33 of 363), 8.2% (34 of 381), 15.9% (68 of 360), and 18.8% (81 of 351) of E. coli isolates in 2009, 2010, 2011, 2012, and 2013, respectively. The incidence of ESBL-producing E. coli was significantly different between 2011 and 2012 (P < 0.05).

**Discussion**

In this study, we observed an increased incidence of ESBL-producing strains in E. coli isolated from blood in this hospital during the five-year period, especially a rapid and statistically significant increase from 2011 to 2012 (8.2% vs. 15.9%). Overuse of third-generation cephalosporins might be a possible reason because the use of third-generation cephalosporins has increased in this hospital since 2012. However,
further investigations are still necessary to explore other possible reasons. This phenomenon is concerning and should be observed closely. Until the incidence of ESBL-producing E. coli has declined, carbapenems may be the most reliable empiric therapy for infections probably caused by E. coli, especially severe infections.

Abstract ID: 2872

The influences on antimicrobial prescribing behaviour in nurse prescribers: a systematic review

Valene Ness, Lesley Price, Kay Currie, Jacqui Reilly
Glasgow Caledonian University, Health Protection Scotland

Introduction

Antimicrobial resistance (AMR) is an urgent public health concern and threatens to reduce the effectiveness of antimicrobials. High consumption, increased frequency and imprudent use of antimicrobials are believed to accelerate resistance and research suggests that inappropriate prescribing is apparent in practice. With a growing number of nurses prescribing antimicrobials, generating an understanding of their practice is essential to inform future strategies designed to combat AMR. Therefore the objective of this review was to systematically identify, appraise and synthesise the evidence in relation to the influences on independent nurse prescribers’ (NPs) antimicrobial prescribing behaviour.

Methods

A comprehensive search strategy was undertaken: databases (AMED, CINAHL, MEDLINE, Health Source: Nursing/Academic Edition), conference proceedings and reference lists were searched for English language studies from January 1st 2002 to 31st December 2013. Records identified were screened for relevance. Two independent reviewers assessed the methodological quality of the papers using critical appraisal tools and data was extracted.

Results

Five studies were found which explored influences on NPs’ antimicrobial prescribing behaviour and two which explored both NPs and doctors/physician assistants. Methodologically, survey design was most common with only one study adopting a qualitative approach. Guidelines, safety, tolerability and efficacy of the antibiotic and diagnostic uncertainty were the most common influencing factors. Other factors such as the clinical condition of the patient and patient/parent pressure, training/experience, peer support, cost, race and payment factors were also mentioned within the studies.

Discussion

These studies were limited by relatively poor response rates, small sample sizes, designs with no agreed theory and often failure to explore the underlying reasons. A methodology which allows for a more thorough exploration of all influencing factors on prescribing behaviour may be more useful to inform future behavioural strategies designed to be inclusive and relevant to this ever increasing group of prescribers.

Abstract ID: 2890

To evaluate the role of biochip for identifying non-tuberculous mycobacteria

Hui-Jine Hsu, Wen-Liang Yu, Mei-Feng Lee, Sheng-Tsung Chang
Chi Mei Medical Center, Tainan, Taiwan

Introduction

In the last two decades, the trend of pulmonary disease caused by non-tuberculous mycobacteria (NTM) seems to be increasing globally. Because the species of NTM causing diseases and consequences vary by geographical distribution, the therapeutic options are different. However, the traditional culture method (TCM) is complicated and time-consuming. Hence, it is very important to adopt a fast method to identify different NTM, resulting in the optimal treatment. The aim of this study was to evaluate the role of identifying NTM by a biochip (DR Chip Biotech, Inc., Taiwan) method, a rapid diagnostic molecular method.

Methods

This was a retrospective study at Chi-Mei medical center in southern Taiwan. From January to December 2013, all clinical samples sent for identifying NTM were enrolled in this study. The methods for identifying NTM included both biochip and TCM.

Results

A total of 6819 samples, mostly obtained from sputum, were enrolled in this study. The detectable rate of NTM was 7.5% (n=510) and 6.9% (n=473) by biochip and TCM, respectively. Moreover, biochip can further distinguish 15 of the most common species of NTM in Taiwan with an accuracy rate of >99% among all NTM-positive species. Of the 510 NTM isolates, the first five NTM species were Mycobacterium intracellulare (n = 197, 38.6%), Mycobacterium kansasi (n = 113, 22.2%), Mycobacterium abscessus (n = 107, 21%), Mycobacterium gordonae (n = 45, 8.8%), and Mycobacterium fortuitum (n = 31, 6.1%).

Discussion

As a result of this study, the application of biochip can not only quickly identify NTM but also distinguish different NTM species. Hence, we consider that biochip may help physicians to prescribe the optimal antibiotics for treating infections caused by NTM.

Abstract ID: 2987

Reducing the use of antibiotics in multi-resistant organisms in urine specimens

Lynn Barton
Cheshire and Wirral Partnership NHS Foundation Trust

Improvement Issue and Context

The Infection Prevention & Control (IPC) Community Team reviews, and communicates to relevant others, every positive microbiology urine result. From this response, it is possible to determine that antibiotic therapy reflects the microbiology result and follows the agreed antibiotic formulary. This initiative enabled us to identify ways to support a community-wide reduction in the use of antibiotics for multi-resistant organisms in urine specimens, and develop a pathway for safe catheterisation, which prevents infections associated with urethral and suprapubic catheters.

Methods and measurement

The IPC team produced guidance for community staff in the assessment, diagnosis and treatment of Urinary Tract Infections (UTIs), emphasising issues such as dehydration, inaccurate urine sample collection, inaccurate diagnosis and management of recurrent UTIs. The IPC team introduced a community catheter pathway for staff, which supports screening and decolonisation for MRSA; reason for catheterisation and consideration for prompt removal. A successful business case enabled a bladder scanner to be purchased for out of hours care to support a trial without catheters in the community setting. Patients were educated regarding self-care of their catheter, when to seek help or advice, and given a leaflet for reference. Patients were scheduled for review at 10 weeks; this allowed the nurse to assess patients within the manufacturer’s licence, considering contingencies, and allowed action if the patient was found to be symptomatic of a systemic Catheter Associated Urinary Tract Infection.

Evidence of Improvement

Feedback from staff for the pathway has been positive; the numbers of inappropriate specimens of urine and antibiotic prescribing have reduced. A collaborative approach to urine specimens has proven successful, promoting communication with all key stakeholders.

Future Steps

This work is ongoing in terms of communications with colleagues across the health and social care community. Education and guidance will be extended to domiciliary services, and care homes.
Abstract ID: 2789

**Integrating a diverse infection prevention team and driving organisational improvement using the John Adair Leadership Model**

Tracey Cooper  
Betsi Cadwaladr University Health Board

**Improvement Issue and Context**  
An experienced senior Infection Prevention Nurse took up post 1 year ago in a large NHS organisation, which has major challenges with infection rates. Three legacy organisations with very different cultures were merged to form this organisation. Each had its own infection prevention service, with different profiles, priorities and working practices. At merger these three services combined from a financial perspective, but never merged to become a single service.

The challenge has been to bring these very different services and historic cultures together in order to achieve an effective organisation-wide infection prevention service that facilitates high standards of effective infection prevention practice.

**Methods and Measurement**  
Leadership and change theories have been utilised by the newly-appointed senior nurse. The John Adair Leadership Model was selected as a useful approach for working with individuals and legacy teams, with the aim of effecting change within the Infection Prevention Team, and across the wider organisation. This approach combined with use of the John Kotter Change Model to drive improvement across the whole organisation is described, along with the leadership challenges this presents.

**Evidence of Improvement**  
Measuring the effectiveness of the leadership approach to achieve this type of cultural and individual behavioural change is not easy. There are however, numerous examples of ‘before and after’ behaviours which demonstrate how the approach taken is resulting in different thinking and working practices.

**Future Steps**  
Work with individuals within the team continues, including developing their leadership skills and encouraging their use of the John Adair Leadership Model. The key elements of the leadership model also continue to be used as part of wider work across the organisation. The aim is to engage staff, and deliver the scale of change needed to protect patients from avoidable infection.

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Abstract ID: 2841

**Improving standards of infection prevention and control practice in St John Ambulance (SJA) through our communications strategy**

Stevie Slade, Marsha Farquhar  
St John Ambulance

**Improvement issue and context**
St John Ambulance underwent a restructure in 2013 from 42 Counties, to a model of 8 regional teams. This was partly to bring greater consistency to operations across the organisation and provided an opportunity to simplify policy implementation; furthermore, the new structure includes an IPC lead in each region to be responsible for overseeing IPC activities and cascading information.

**Methods and Measurement**
Numerous communications relating to IPC practice have been produced and implemented following the restructure:

- **IPC National Advisory Group activities**
  - Materials produced, such as the development of a sharps injury management poster.

- **Evidence of improvement**
  - Increased awareness can be seen in several areas: IPC posters and other materials have been displayed regionally; audits have showed raised standards and increased compliance.
  - The IPC National Advisory Group members have also provided positive feedback on IPC campaigns.

- **Future steps**
  - Examples of planned work include launching a monthly clinical e-newsletter to include IPC articles and to plan more national activities like the hand washing day and reporting of these on the intranet. We also aim to increase the national provision of IPC resources, such as cleaning chemicals and clinical waste collection, to be communicated via the IPC National Advisory Group and news stories.

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Abstract ID: 2879

**Gaming theory, social media and human factors - catalysing an epidemic of evidence uptake**

Jules Storr1, Claire Kilpatrick1, Gary Thirkell2, Neil Wigglesworth3
1KS-Healthcare Consulting Ltd, 2Leeds Teaching Hospitals NHS Trust, 3Public Health Wales

**Improvement issue and context**
The use of game theory and social media as a mechanism for generating interest in research findings is a groundbreaking approach to engaging healthcare professionals. Being able to excite busy professionals to apply evidence based research findings into practice is subject to multiple barriers.

**Method**
Using a hybrid of a well established game, Top Trumps® and social media (Twitter), we developed a novel ‘TopTrumpitter’ visualisation to enhance understanding, and enable access and practical translation of key articles on human factors and infection prevention and control (IPC). Twitter was used to provide a description of articles in 140 characters.

A five-part TopTrumpitter grading criteria was developed, with scores ranging from 0 to 10: 1) Relevance - method employed, impact on prevention. 2) Wow factor - reader wants to keep reading after the first seven words. 3) Immediate change to practice - unambiguous, implementation-focused. 4) Must read - engaging language and references stimulating further reading. 5) Bonus point - reader motivated to tell someone else to read/tweet about it.

**Findings**
From 3000 titles, 129 abstracts and 52 full text papers were reviewed and 33 retained. Visualisations were created on the top 6 articles using a TopTrumps-like
format. The Twitter-approach enabled articles to be summarized succinctly. The final component of the visualisation scored each paper using the TopTrumpitter criteria.

Discussion
This approach builds on the call to action recommended by Storr et al. It allows for an engaging presentation of article reviews to reach out to a wider audience.

In the 21st century, where the use of mobile technology and social media is expanding and the cognitive capacity of frontline practitioners is compromised by information overload, new approaches to visualising research findings have great potential to stimulate debate and influence practice.

Reference


Abstract ID: 2929

TeamGreen A pilot study exploring the potential of ATP (Adenosine Triphosphate) screening to increase healthcare professional engagement with environmental cleaning

Carolyn Dawson, Fiona Reakes
Wells University Hospitals Coventry and Warwickshire Trust (UHCW)

Introduction
Lack of engagement can make implementation and sustainability of infection prevention interventions difficult. A pilot study within an NHS acute setting explored the potential of ATP (Adenosine Triphosphate) screening to increase healthcare professional engagement with environmental cleaning (EC). ATP screening within infection prevention has been widely discussed. However, application to engagement appears novel.

Methods
Semi-structured interviews with senior nursing staff (N=2) were conducted pre and post interactive sessions to establish: perceived level of EC “engagement”. 13 interactive sessions occurred over five weeks, involving healthcare professionals from a range of clinical grades (N=8). Sessions utilised the 3M Clean-Trace Hygiene Management System. An IPC nurse aided participants conduct ATP screening of: Cardiac Arrest Trolley, Drip Stand, Dynapam Base, Notes Trolley Draws, and SATS Probe. Participants recorded Relative Light Unit (RLU) counts for each surface. Easy to understand data was generated: participants reported difficulties engaging staff in EC discussions, not everyone saw it as “their job”. Interactive sessions generated high engagement, determined by the emergence of a “want to clean” culture (Table 1).

Encouragingly, RLU counts fell across all five areas. Post-interactive session data was used to identify rooms for CRE screening. Post-interactive sessions were validated (summer 2014), with additional wards involved with interactive sessions (autumn 2014).

Results and Discussion
Data collection occurred July-August 2013. Interviews revealed low data ownership, and perceived level of EC “engagement”. 13 interactive sessions occurred over five weeks, involving healthcare professionals from a range of clinical grades (N=8). Sessions utilised the 3M Clean-Trace Hygiene Management System. An IPC nurse aided participants conduct ATP screening of: Cardiac Arrest Trolley, Drip Stand, Dynapam Base, Notes Trolley Draws, and SATS Probe. Participants recorded Relative Light Unit (RLU) counts for each surface. Easy to understand data was generated: Red >2000; Amber 1000-2000; Green <1000 RLU. Green was the target status.

If there was a “yes” to any of the questions, then the patient was nursed with contact precautions, and GNR screen taken (rectal swab) on admission, and then every 48 hours until three samples had been obtained. Patients who were found to be CRE positive were to be nursed in a side room, and contacts “followed up”.

Future Steps
For an implementation of CRE screening programme, a formal educational process should be devised. There should be a mechanism in place so that Senior Clinical Staff and Medical Teams may be able to raise any issues which may be dealt with. The screening tool should be stored electronically, with the rest of the patient’s records, which may also serve as a checking mechanism for screening programmes.

Abstract ID: 2946

Admission Screening for gram negative resistance

Madeleine Farren, Andrew Letters
King’s College Hospital NHS Foundation Trust

Improvement issue and context
A new resistant organism, carbapenem resistant Enterobacteriaceae (CRE), has emerged, which is problematic due to resistance and ease of spread. Patients who are colonised with CRE must be identified, so that the appropriate control measures may be implemented. In a busy acute Trust, the Microbiologist requested a short pilot study to establish if screening for CRE was feasible for emergency admissions. This pilot was to highlight any problems with a CRE screening programme.

Methods and measurement
The pilot was to be run for a week, with CRE risk assessment paper tool (as below) to be done on admission:

<table>
<thead>
<tr>
<th>Risk assessment</th>
<th>Yes / No</th>
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<tbody>
<tr>
<td>1. History of CRE colonisation or infection anytime in the past?</td>
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<tr>
<td>2. Healthcare admission abroad in last 12 months?</td>
<td></td>
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<tr>
<td>If yes, record the name of the country</td>
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<tr>
<td>3. Healthcare admission in Manchester, London (within M25) or Northwest England in the last 12 months?</td>
<td></td>
</tr>
<tr>
<td>If yes, record the name of the hospital</td>
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</table>

If there was a “yes” to any of the questions, then the patient was nursed with contact precautions, and GNR screen taken (rectal swab) on admission, and then every 48 hours until three samples had been obtained. Patients who were found to be CRE positive were to be nursed in a side room, and contacts “followed up”.

Evidence of improvement
Day one, just over 40% of new admissions were risk assessed which rose to nearly 90% by day 8.

Abstract ID: 2969

Developing the infection prevention and control Health Care Assistant role

Darren Wheldon
University Hospitals Coventry and Warwickshire NHS trust

Improvement issue and context
The Infection Prevention and Control Team (IPC) had changed their ethos from highlighting poor practice to a support and knowledge resource as historically we were seen as the “police force”. Therefore, the role of the IPC healthcare assistant (HCA) needed to develop in line with this change. Staff now required someone to work closely with them to assist and lead with their ward based IPC education.
We needed consistent education on topics such as hand hygiene and environmental cleanliness to be delivered to all levels of staff in a meaningful way.

**Methods and Measurement**

Regular ward visits from the HCA were commenced to highlight specific ward needs and therefore be able to provide education that is applicable to them. Walkarounds with the executive management team have become commonplace to reinforce key messages to all staff. Hand hygiene and environmental audits are undertaken routinely and discussed at monthly operational meetings where Modern Matrons attend. This was designed to create an environment where all staff feel confident to be able to check and challenge colleagues and ensure IPC is regarded as part of creating a safe environment for patients.

**Evidence of Improvement**

We now see more motivated and enthusiastic staff who state ‘IPC is an integral part of patient care rather than seen as an add on’. We have noted that commitment from the executive team encourages and motivates staff resulting in a fantastic positive attitude towards IPC. Hand hygiene compliance has increased and sustained a level of greater 90% and environmental audits for example have increased from 68% to 89% since the role developed.

**Future steps**

Currently in the process of creating a user friendly poster on how to clean commodes. Also, looking to develop peripheral cannulation education using existing gaming technology.
Abstract ID: 2816

Antimicrobial activity of Eucalyptus globulus oil, xylitol and papain

Vanessa De Brito Poveda1, Valéria De Siqueira Mota2, Ruth Natalia Teresa Turrini1, Rúbia Aparecida Lacerda1
1University of São Paulo, Brazil, 2Teresa D’Ávila University, Spain.

Introduction
Germicides have been used indiscriminately in health care environments, often at much higher concentrations than recommended minimum inhibitory concentration, which has encouraged the development of microbial resistance to these agents. The goal of this study was to evaluate the antimicrobial activity in vitro of Eucalyptus globulus essential oil, 10% xylitol, 20% xylitol, 10% papain and 20% papain against the following microorganisms: Pseudomonas aeruginosa; Salmonella spp; Staphylococcus aureus; Proteus vulgaris; Escherichia coli and Candida albicans.

Methods
Therefore, in vitro antimicrobial activity was tested through agar disk-diffusion test and evaluation of the diameters of inhibition halo of the substances tested. Chlorhexidine 0.5% was used for control.

Results
It was observed that the inhibitory activity of Eucalyptus globulus was superior to that of chlorhexidine when applied to the microorganism Staphylococcus aureus and identical to Escherichia coli, Proteus vulgaris and Candida albicans. The 10% papain showed an antimicrobial effect inferior to that of chlorhexidine when applied to Candida albicans. The substances, 10% xylitol and 20% xylitol, showed no inhibition of the tested microorganisms.

Discussion
The antimicrobial activity of Eucalyptus globulus essential oil is superior to that of chlorhexidine when applied to the gram-positive bacteria tested. Thus, it can be inferred that the essential oil of Eucalyptus globulus has antimicrobial activity against the strains of microorganisms tested and can be a viable alternative as an antiseptic agent. It reinforces the need for new investigations, seeking evidence of its pharmacological and germicidal properties.

Abstract ID: 2867

Disinfection of hospital environmental surfaces with sodium hypochlorite: a systematic review

Samantha Storer Pesani Pereira, Vanessa De Brito Poveda, Ruth Natalia Teresa Turrini, Rúbia Aparecida Lacerda
University of São Paulo

Introduction
Sodium hypochlorite is one of the most used disinfectants for environmental surfaces, although new products and technologies for disinfection procedures are emerging.

Objective
To review the evidence for the efficacy of disinfection with sodium hypochlorite of environmental surfaces to prevent contamination and healthcare-associated infection.

Methods
This study used the Cochrane Handbook for Systematic Reviews. The search was performed from December 2013 to February 2014 using COCHRANE, LILACS, PUBMED/MEDLINE, SCIELO, CINHAL databases.

Results
We analysed 16 controlled experimental studies, one of which was randomized, one cross-over and two were before and after comparisons. They were published between 1989 and 2013. Almost all studies showed favourable results in terms of microbial growth or inhibition by hypochlorite action (10), reduction of infection (5), microbial resistance (1) and colonization (2). Two studies showed loss of efficacy, one in the presence of heavy soiling with blood and another when tested for rehydrated dried virus. Hypochlorite showed higher antimicrobial efficacy, including spores, and broad antimicrobial activity, longer exposure time and higher concentration allowing longer action compared with other disinfectants.

Discussion
Hypochlorite is an effective disinfectant for environmental surfaces. However, the studies that have sought the relationship between its use and infection reduction didn’t control important confounding variables. Despite many studies with similar design, meta-analysis was not possible because of the diversity of strategies used to conduct and measure the effect of the interventions, relating to: the origins and types of microorganisms, sampling and laboratory testing, culture media, types of surfaces, product concentration and contact time. The CONSORT and TREND protocols for evaluation of internal validity were inappropriate to the nature of these studies, so is urgent the development of specific protocols for evaluation of laboratory and microbiological studies.

Abstract ID: 2873

Improving compliance with hydrogen peroxide vapour automated room disinfection at National University Hospital, Singapore

Sharon Salmon, Dale Fisher, John Leong, Liene Chong, Jean Chang
National University Hospital, Singapore

Improvement issue and context
Since 2006 NUH has been implementing robust active surveillance, isolation, cohorting and improving hand hygiene compliance for health care workers. However recently we have detected incremental increases in MRSA bacteraemias. Further, MRSA hospital acquisitions have now reached a plateau with rates difficult to reduce below 2.5%. Importantly, we are also experiencing increases in other hospital acquired infections caused by multi-drug resistant organisms (MDROs). We recognized a need to escalate our efforts in environmental decontamination. NUH introduced hydrogen peroxide vapour (HPV) technology to decontaminate each room following the discharge of a patient known or suspected of being infected or colonised with a MDRO.

Methods and measurement
To achieve this goal we engaged in a pilot trial using HPV (Bioquell Q10) to understand the feasibility of introducing and integrating new technology into our existing workflows. Subsequently, NUH purchased five Q10 suites to integrate into our environmental decontamination approach for high risk areas.

Evidence of improvement
The pilot trial demonstrated operational feasibility. Since then, 1733 deployments using five Q10 suites have been completed (August 2013 – May 2014), comprising 98% single rooms and 2% shared equipment. Each Q10 is used on average once per day (1.0 – 1.3). Deployments are based on patients known to be infected or colonized with pathogens based on a priority list of organisms for significance for NUH. Usage has been extended to include other inpatient areas experiencing increases in MDRO acquisitions or for outbreak control including cleaning of common shared equipment.
Future steps
HPV service has become integrated into hospital operations. We plan to further optimize the service by extending services to be available 24 hours/7 days per week, and tracking and reporting HPV utilization based on priority organism.

Abstract ID: 2874
Incidents related to failed decontamination of endoscopes and surgical instruments
Paul Southworth, Annette Rankin
Health Protection Scotland

Introduction
Reusable surgical instruments and flexible endoscopes provide potential routes for transmission of pathogenic agents between patients in healthcare facilities. As such, the decontamination process between uses is a vital component in the prevention of healthcare associated infections. Furthermore, advances in technology and expansion of screening programs have led to a great increase in endoscopic procedures in recent years. The aim of this review was to provide an overview of outbreaks, infections and incidents associated with inappropriate, inadequate or unsuccessful decontamination of endoscopes and surgical instruments, providing useful context to national guidelines.

Methods
Databases of medical literature, Medline and Embase, were searched systematically. Articles detailing incidents associated with unsuccessful decontamination of surgical instruments were identified.

Results
147 articles were identified reporting incidents associated with unsuccessful decontamination of endoscopes, while 21 articles were found for surgical instruments. Breaches in each stage of the process of endoscope decontamination were associated with incidents, with bronchoscopy (54% of articles), endoscopic retrograde cholangiopancreatography (ERCP) (19%) and upper-gastrointestinal endoscopy (16%) most commonly reported. Organisms most commonly identified in endoscope breaches include Pseudomonas aeruginosa (29% of relevant articles) and Mycobacterium spp. (23%). However, recent years have seen carbapenemase-producing Klebsiella pneumoniae become the most commonly reported organism.

Discussion
Decontamination incidents associated with endoscopes continue to be extensively reported in the medical literature. Changes in the pathogens seen, as well as the emergence of incidents where no breach can be found in the decontamination process merit urgent investigation and further research. In contrast, the small number of articles identified detailing surgical instrument decontamination failures underlines the low risk of cross-infection and highlights the robust nature of instrument sterilisation practices. The diverse nature of reported surgical instrument incidents also suggests that failures are not systemic. However, the possibility to publish failures must be considered, with incidents going unreported.

Abstract ID: 2888
Phase 3 testing of an ultra-high level sporidical disinfectant: The missing link between laboratory based efficacy and clinical performance
Chris Woodall
BluTest laboratories Limited

Introduction
Common variables between laboratory suspension tests and real world disinfectant use include: Delivery method - are suspension tests relevant for disinfectants which are delivered via cloths, wipes, spray mists, etc.? Contact time - are 60 minute wet contact times clinically relevant? Controlled field testing or ‘phase 3 testing’ bridges the gap between in-vitro efficacy and clinical effectiveness. Testing takes place in clinical settings where a known bioburden of a specific organism is exposed to a disinfectant delivered in its normal way. This work used phase 3 testing to determine the effectiveness of an ultra-high level disinfectant against validated Clostridium difficile spores.

Methods
A 32m² unfurnished isolation room was used. Prior to disinfection 10 plates were placed on horizontal and vertical surfaces, including the ceiling. Plates contained 9 slides. Each slide was inoculated with up to $1 \times 10^6$ C. difficile spores dried onto its surface. An ultra-high level sporidical disinfectant was dispensed throughout the room via a centrally located, specialist, mains powered misting system over a 7 minute period. After 43 minutes dwell-time, plates were collected and processed in the laboratory by neutralisation and then for C. difficile viability. After neutralising, plates onto Columbia agar and incubating anaerobically at 37°C for 3 days, microbial growth was reported.

Results
5.6x10^5 cfu were recovered from the control with no exposure to the disinfectant. <1.4x10^3 cfu were recovered at the 10 test locations.

Discussion
The test disinfectant proved highly effective against C. difficile spores in a clinical setting. Both delivery method and contact time are clinically appropriate for this specific disinfectant. Phase 3 testing offers manufacturers and customers significant insight into disinfectant performance in the clinical setting and may assist decision makers when adopting new disinfectants into clinical practice.

Abstract ID: 2889
Using a new low temperature, non-corrosive laundry system to improve the cleanliness of high performance mattresses and reduce energy costs associated with the laundry process
Kathryn Lees
Manchester Metropolitan University

Improvement issue and context
To reduce the risk of cross-infection, high-performance mattresses must be effectively cleaned and decontaminated prior to re-use. This is achieved either via heat (75°C) or chemical exposure i.e. chlorine releasing agents. Regular exposure to either of these factors can damage mattresses which can be an important cross-infection issue. The laundry process itself and replacing damaged or worn mattress covers / components represent significant costs for mattress providers, Trusts, loan stores etc. managing fleets of specialist air mattresses. The improvement issue was to identify a more energy efficient laundry process which could deliver equivalent or improved mattress cleanliness without exposing products to excessive heat or corrosive chemicals.

Methods and measurements
A 4-week evaluation at a commercial laundry compared the standard laundry process (75°C) with a new system combining a specialist detergent with a non-corrosive, high level disinfectant rinse at 35°C. Primary outcome was mattress cleanliness. Swabs were used to quantify microbial bioburden (total viable count (TVC)) pre and post-laundry for 20 mattresses going through the laundry. Secondary outcomes included process efficiency (water usage and energy expenditure).

Evidence of improvement

<table>
<thead>
<tr>
<th>Outcomes</th>
<th>Standard process (75°C)</th>
<th>New process (35°C)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean TVC on mattresses</td>
<td>Before laundry</td>
<td>10^5</td>
</tr>
<tr>
<td>Wash cycle duration</td>
<td>After laundry</td>
<td>10^2</td>
</tr>
<tr>
<td>Wash time duration</td>
<td></td>
<td>64 minutes</td>
</tr>
<tr>
<td>Total water usage</td>
<td></td>
<td>276 litres</td>
</tr>
</tbody>
</table>
The new system creates cleaner mattresses, which reduces the risk of cross-
contamination prior to re-use of the products. In addition the new process
reduces the wash temperature by 40°C and saves 22 minutes (34%) of time and
111 litres of water (40%) per wash cycle.

Future steps

The commercial laundry has adopted the new laundry wash system where it has
now been successfully used for 18 months. In addition to improving mattress
cleanliness the laundry has increased mattress throughput and recorded a 53%
energy saving as a direct result of employing the new system.

Abstract ID: 2898

Establishing a national protected bedspace discharge cleaning time

Paul M. Southworth, Jackie McIntyre, Annette Rankin
Health Protection Scotland

Improvement Issue and Context

With increasing demand for hospital beds, pressure is often applied to nursing
and housekeeping staff to supply free beds ASAP after patient discharge. Rushing
discharge cleaning or giving insufficient time to clean has the potential to result in
inadequately decontaminated patient environments and cross-transmission of
pathogenic agents. We sought to establish a protected timeframe for nurses/
cleaning staff to complete bedspace discharge cleaning before the following
patient can be admitted. This time is to be applicable for different ward-types (e.g.
ICU, psychiatry etc.) and bedspace-types (e.g. single room, four-bed bay etc.). A
methodology was developed and a study undertaken to establish how long such
cleaning takes and if this time differs within and between specialties.

Methods and Measurement

A basic methodology including a cleaning checklist and measurement tool were
piloted in one NHS Scotland Health Board. The checklist and tool were assessed
according to their usefulness and usability by staff responsible for hospital clean-
ing and were subsequently altered according to feedback received during this
pilot. The adjusted tools were then used in six NHS Scotland Health Boards to
measure time taken to clean in a variety of contexts.

Evidence of Improvement

National protected cleaning times were established as a result of this study, giving
further support to housekeeping services and nursing staff involved in discharge
cleaning. The checklist and measurement tools were well received and considered
self-explanatory by those undertaking the study and staff welcomed the opportu-
nity to help establish a protected time. Details on similarities and differences in
cleaning times between different areas have also provided useful information as to
differences in cleaning strategies.

Future Steps

We are now seeking to progress the protected cleaning time to a national policy.
Consultation with key stakeholders including nursing and housekeeping staff will
continue to assess the usefulness of this time.

Abstract ID: 2902

Improving process efficiency and medical device cleanliness at a
Foundation Trust by adopting a new combined cleaner/disinfector into
routine use in a busy Medical Device Library

Gary Embleton
Lancashire Teaching Hospitals NHS Foundation Trust

Improvement issue and context

Effective cleaning of equipment is essential prior to devices being loaned from the
Medical Device Library (MDL). Inadequately cleaned devices pose a potential
infection risk to patients, MDL staff and Medical Engineers. Historically routine
MDL device cleaning involved two-stages; Step 1. Washing with neutral detergent
solution and or wipes. Step 2. Drying with paper towels. The improvement aim
was to identify a new method of device cleaning which would maintain device
cleanliness whilst simultaneously improving process efficiency and reducing
waste from the cleaning process.

Methods and measurement

A new combined cleaner/disinfector, permitting a single stage cleaning process,
was identified and evaluated within a busy MDL at a Foundation Trust. Medical
device cleanliness was determined using adenosine triphosphate (ATP) swab
testing of ten devices before and after standard (detergent-based) cleaning and
when using the new cleaner/disinfector. Process efficiency was assessed by per-
forming formal time-and-motion assessments when processing ten devices with
both the standard and the new cleaning process.

Evidence of improvement

The time-and-motion studies demonstrated clear improvements with a >50% effi-
ciency saving when using the new product. ATP scores demonstrate medical
device cleanliness was on average 50% cleaner when using the new cleaner/disin-
fector compared to the standard process, thereby reducing further any potential
infection risk to patients. MDL staff and Medical Engineers. The new process
eliminated the use of paper towels. This significantly reduced the waste produced
when cleaning devices.

Future steps

The MDL have adopted the new cleaner/disinfector into routine use for all device
cleaning. The new product has improved departmental efficiency, reduced waste
associated with product cleaning and resulted in cleaner equipment.

Abstract ID: 2919

A pilot study of the use of pulsed-xenon ultraviolet disinfection in a UK
hospital

Edward James1, Natalie Mac Donald1, Alan Catto2, Julie Gubb2, Mark Stibich2
1NHS Borders, 2Xenex Healthcare Services

Introduction

No touch disinfection methods have attracted interest as methods of reducing envi-
ronmental contamination with pathogens. Pulsed-Xenon Ultraviolet (PX-UV) is a
means of producing ultraviolet light that yields ultraviolet C throughout the germicidal
spectrum. The purpose of this pilot study was to evaluate the efficacy of PX-UV in
reducing the level of environmental contamination in patient areas in a UK hospital.

Methods

During a period of increased norovirus activity, high touch frequency sites were
identified in an affected bay. five single rooms and their toilets. Contact plates
were taken from sites after terminal cleaning (post clean). The area was treated
with PX-UV and repeat samples taken from adjacent areas at the same site (post
PX-UV). One operating theatre was also sampled. Total aerobic colony counts
were performed after 48 hours incubation. The worker reading the plates was
blind to the sample site and timing in relation to PX-UV treatment.

Results

The number of surfaces with no growth (CFU=0) after sampling in the post-
growing group was 3 (4.0%) while in the post PX-UV group the number of no
growth surfaces was 31 (41.3%). The number of surfaces with less than 5 CFU
were 17 (22.6%) and 52 (69.3%) for the post clean and post PX-UV groups,
respectively. The total CFU in the post clean group was 5959 while in the post
PX-UV group, the total CFU was 1089; this led to a mean CFU of 79.4 and 14.5
for the post clean and post PX-UV groups respectively. representing an 81.7%
reduction p<0.0001 (Wilcoxon rank-sum test).

Discussion

The PX-UV device reduced bacterial contamination after terminal cleaning. This
additional disinfection was accomplished in a relatively short time on multiple
A total of 67 large area burn patients from 2012 to 2013 were enrolled in the study.

**Conflict of Interest**

Three of the co-authors on this abstract are employees of Xenex Healthcare Services who manufacture the device used in the study.

**Abstract ID: 2931**

Cause analysis of *Pseudomonas aeruginosa* infections in large area burn Patients

Jia-Ke Chai, Shu-Jun Wang, Cong-Ying Liu
Burns and plastic surgery department, First Affiliated Hospital of Chinese PLA General Hospital

Introduction

To explore the causes of *Pseudomonas aeruginosa* infections in large area burn patients in burn unit and propose preventive measures.

Methods

A total of 67 large area burn patients from 2012 to 2013 were enrolled in the study. In total, 350 samples were collected for bacterial culture including 134 samples from burn wounds, 216 samples from object surface in laminar flow clean room, hands of medical staff, object surface in treatment room, keyboards and door knobs.

**Results**

In the 350 samples, 41 samples were positive with *P. aeruginosa*, therefore the positive rate is 11.7%. The positive rate of the samples from burn wounds was 18.7%; the positive rate of the samples from object surface in laminar flow clean room was 10.4%; the positive rate of the samples from hands of medical staff was 12.5%; the positive rate of the samples from object surface in treatment room was 0%; the positive rate of the samples from door knobs and keyboards was 8.3%.

**Conclusion**

*P. aeruginosa* infections in large area burn patients may be from hands of medical staff, object surface in laminar flow clean room, and door knobs and keyboards. Strengthening the management of medical staff, strict disinfection and isolation should be implemented in burn unit to prevent *P. aeruginosa* infections in large area burn patients.

**Abstract ID: 2932**

Problems in connection with cleaning hospitals with Methicillin-resistant *Staphylococcus aureus* in Japan - Interviews with four Infection Control Nurses

Michiko Morimoto
University of Hyogo, Japan

Introduction

The cleaning of hospital rooms with MRSA infection in Japan is managed differently according to each institution. The purpose of this study is to specify the problems of cleaning hospitals with MRSA infection using interviews with the infection control nurses.

**Method**

We studied interviews with four infection control nurses at four hospitals in Hyogo prefecture of Japan, each hospital has 100 beds. Interviews were carried out for 30 minutes using a semi-structured data collection process and an interview guide. During the interview, questions were asked to those interviewees about cleaning up MRSA infections: focusing on cleaning methods, training and challenges. The interviews were recorded as a verbatim record. In order to highlight the problems of the cleaning (KH Coder Ver.2β31) analysis software was used. This was utilized in order to create an extractable data base using search words (noun, adjective verb, verb, etc)

Ethical considerations: Our method and design were accepted with the approval of the research ethics committee of the university.

**Results**

This project resulted in the establishment of an ICT, environment, cleaning, measures, outbreaks, committees, management (individuals), hearing, touching, wards, prevention, activities, carry-in, hand-washing observations, suppliers, auxiliaries, infection control nurse, and education items.

**Discussion**

This data has brought to our attention that the major causes of infection are not generally due to personal contact between medical process and patients, but are usually due to more broad environmental causes. Therefore, it is advisable that nurses take more notice of environmental conditions rather than delegating this to non-medical staff.

**Abstract ID: 2934**

ENCOMPASS Hygiene Intelligence System: Does it help to improve theatre cleaning between cases?

Sara Silver, Clive Stasin, Shazad Raja
Royal Brompton and Harefield NHS Trust

Introduction

A total of 67 large area burn patients from 2012 to 2013 were enrolled in the study. In total, 350 samples were collected for bacterial culture including 134 samples from burn wounds, 216 samples from object surface in laminar flow clean room, hands of medical staff, object surface in treatment room, keyboards and door knobs.

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**Conclusion**

*P. aeruginosa* infections in large area burn patients may be from hands of medical staff, object surface in laminar flow clean room, and door knobs and keyboards. Strengthening the management of medical staff, strict disinfection and isolation should be implemented in burn unit to prevent *P. aeruginosa* infections in large area burn patients.

**Abstract ID: 2922**

Staphylococcus aureus in Japan - Interviews with four Infection Control Nurses

Michiko Morimoto
University of Hyogo, Japan

Introduction

The cleaning of hospital rooms with MRSA infection in Japan is managed differently according to each institution. The purpose of this study is to specify the problems of cleaning hospitals with MRSA infection using interviews with the infection control nurses.

**Method**

We studied interviews with four infection control nurses at four hospitals in Hyogo prefecture of Japan, each hospital has 100 beds. Interviews were carried out for 30 minutes using a semi-structured data collection process and an interview guide. During the interview, questions were asked to those interviewees about cleaning up MRSA infections: focusing on cleaning methods, training and challenges. The interviews were recorded as a verbatim record. In order to highlight the problems of the cleaning (KH Coder Ver.2β31) analysis software was used. This was utilized in order to create an extractable data base using search words (noun, adjective verb, verb, etc)

Ethical considerations: Our method and design were accepted with the approval of the research ethics committee of the university.

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This project resulted in the establishment of an ICT, environment, cleaning, measures, outbreaks, committees, management (individuals), hearing, touching, wards, prevention, activities, carry-in, hand-washing observations, suppliers, auxiliaries, infection control nurse, and education items.

**Discussion**

This data has brought to our attention that the major causes of infection are not generally due to personal contact between medical process and patients, but are usually due to more broad environmental causes. Therefore, it is advisable that nurses take more notice of environmental conditions rather than delegating this to non-medical staff.

**Abstract ID: 2924**

ENCOMPASS Hygiene Intelligence System: Does it help to improve theatre cleaning between cases?

Sara Silver, Clive Stasin, Shazad Raja
Royal Brompton and Harefield NHS Trust

Introduction

A total of 67 large area burn patients from 2012 to 2013 were enrolled in the study. In total, 350 samples were collected for bacterial culture including 134 samples from burn wounds, 216 samples from object surface in laminar flow clean room, hands of medical staff, object surface in treatment room, keyboards and door knobs.

**Results**

In the 350 samples, 41 samples were positive with *P. aeruginosa*, therefore the positive rate is 11.7%. The positive rate of the samples from burn wounds was 18.7%; the positive rate of the samples from object surface in laminar flow clean room was 10.4%; the positive rate of the samples from hands of medical staff was 12.5%; the positive rate of the samples from object surface in treatment room was 0%; the positive rate of the samples from door knobs and keyboards was 8.3%.

**Conclusion**

*P. aeruginosa* infections in large area burn patients may be from hands of medical staff, object surface in laminar flow clean room, and door knobs and keyboards. Strengthening the management of medical staff, strict disinfection and isolation should be implemented in burn unit to prevent *P. aeruginosa* infections in large area burn patients.
Introduction
It is vital for theatres to be cleaned thoroughly between cases. The operating theatres at our institution are cleaned between cases by theatre staff where each discipline is responsible for cleaning their specific equipment. The aim of this study was to determine the efficacy of cleaning between cases and whether this could be improved by actively monitoring prescribed areas.

Method
An invisible gel, easily removed upon regular wiping, was applied to 18 high touch objects in the theatre environment. This gel fluoresced under UV light which had to be removed without trace in order for the surface to attain a pass.

Phase 1 was a blind approach to create a baseline, the results of which were shared with the team following 12 cardiac surgery cases. Areas for improvement were identified and discussed. Phase 2 was to assess whether discussions were successful in improving standards of cleanliness by applying gel to the same 18 high touch objects in 12 cardiac theatres.

Results
Phase 1: Of the 216 high touch objects that were gelled, 60 passed (28%) with a median of 3.5 per object and a mean of 6 per object. 1/18 passed 100% of the time and 8/18 failed 100% of the time.

Phase 2: Of the 216 high touch objects tested, 129 passed (60%) with a median of 7 per object and a mean of 6 per object. Phase 2 shows an increase in the pass rate of 32% in just one month of repeat testing where 3/18 passed 100% of the time and 0/18 failed.

Discussion
This UV light method has been successful in improving the degree of cleaning in our operating theatres. This is as a direct result of team discussions, knowledge of location of the gel, training as well as improvements in cleaning technique.

Abstract ID: 2960
In-Use sporicidal efficacy of Peracide peracetic acid (PAA) disinfectant solution: In-vitro efficacy and ward assessment
Shanom Ali, Monika Muzslay, Peter Wilson
University College London Hospitals NHS Trust

Abstract ID: 2967
Continually improving cleaning standards and performance in a large NHS Acute Trust
Gary Thirkell
Leeds Teaching Hospitals Trust

Abstract ID: 2975
Environmental assessment of a Critical Care Unit during increased incidence of Clostridium difficile
Rick Catlin, Eimear Donnelly
Aintree University Hospital Foundation Trust

Methods
Simulated cleaning identified surfaces remain contaminated (~3log CD) for up to 60 min if cleaned with tap water or NADCC but 2 log less contamination when Peracide was used.

Discussion
Peracide disinfectant achieved sporicidal efficacies that exceeded the EN criteria (3log reduction within 60min) and demonstrated good potential to reduce/eliminate CD contamination from the hospital environment. User-feedback was positive (fragranced formula with colour activation-system improved usability) and deemed acceptable by hospital staff.

Abstract ID: 2977
Continuing evaluation of sporicidal activity of peracetic acid
S. M. Muzslay
Aintree University Hospital Foundation Trust

Methods
Peracide disinfectant achieved sporicidal efficacies that exceeded the EN criteria (3log reduction within 60min) and demonstrated good potential to reduce/eliminate CD contamination from the hospital environment. User-feedback was positive (fragranced formula with colour activation-system improved usability) and deemed acceptable by hospital staff.

Conflict of Interest
This abstract has been completed with Ecolab using their product/system.
Improvement Issue and Context
The role environmental cleaning plays in the prevention of transmission of health-care acquired infections is consistently recognised. [1] Infection Prevention and Facilities teams require assurance that cleaning is performed thoroughly and effectively, alongside the implementation of appropriate training tools to improve/sustain cleaning performance.

Methods and Measurement
The Trust implemented EnCompass Hygiene Intelligence program to improve cleaning performance across 2 large hospitals within Patient Wards, Intensive Care Units (ICU) and Theatres, measuring: Daily & discharge cleaning in ICU and Patient Wards. Discharge cleaning performed by Rapid Response and Theatre terminal cleaning.

High touch objects are marked prior to cleaning with the fluorescent gel. Using a UV blacklight after cleaning, the full removal of the gel is measured. Results are transmitted to the Trust’s portal which provides realtime trend analysis. Three week baseline period followed by communication to staff, raising awareness of importance of cleaning. Post baseline period, a continuous improvement program was implemented including: Strong communications program, Weekly feedback, 1:1 feedback, Targeted education based on analysis from monitoring.

Evidence of Improvement
All areas significantly improved in comparison to the baseline period.

<table>
<thead>
<tr>
<th>Area</th>
<th>Percentage Improvement</th>
</tr>
</thead>
<tbody>
<tr>
<td>Patient Room</td>
<td>39%</td>
</tr>
<tr>
<td>ICU Daily &amp; Discharge cleaning</td>
<td>37%</td>
</tr>
<tr>
<td>Rapid Response team</td>
<td>40%</td>
</tr>
<tr>
<td>Operating Theatre</td>
<td>64%</td>
</tr>
</tbody>
</table>

Visual auditing scores, already very high, saw a 1-2% improvement with the Encompass interventions.

Future Steps
Continue EnCompass, increasing usage across the Trust and training programs to maintain cleaning effectiveness and efficiency, resulting in assurance for the Trust.


Conflict of Interest
I worked with Ecolab in a workstream which focuses on the content of the poster.
Abstract ID: 2795

Cross-sectional survey of compliance of doctors with infection control measures in the West Bank / Palestine Governmental Hospitals

Ahmed Abu Tayeh, Fadi Zaben, Anis Al Hajjeh, Colin Green, Malik Zaben
International Medical Education Trust 2000- Palestine (IMET2000-Pal)

Introduction
Hospital acquired infections, which can be transmitted from microorganisms on the hands of doctors to patients, remain an important cause of morbidity and mortality of hospitalized patients across the world. Doctors have different practices in adherence to infection control (IC) standards depending on their undergraduate training and possibly experience. This study aims to explore Palestinian doctors’ knowledge of and compliance with IC standards in the governmental hospital. It is expected that this study will identify the IC training needs of this very important subgroup of healthcare workers.

Methods
A multi-centre, cross-sectional, descriptive study, using a self-administered questionnaire, was conducted in October-November 2013. Participants’ knowledge and compliance regarding specific IC policies were examined using a scale of 0-9; 9 is the maximum score. Needs for training were also explored. SPSS was used for data analysis.

Results
90 doctors from 6 governmental hospitals in West Bank responded to our survey; 85.4% males, 27.8% juniors (internship), 61.1% residents and 11.1% consultants. While only 28.9% received training in their local hospitals, their knowledge and compliance scores were 7.5 and 4.7, respectively (maximum score is 9). Juniors had the lowest score of compliance (3.8). Factors including subspecialty, gender and place of work, had no effect on neither participants knowledge nor compliance scores. The vast majority (96.7%) of participants indicated that infection control training is needed or very much needed.

Discussion
While doctors’ knowledge of IC standards is fairly acceptable, their compliance with these standards is unacceptably low. Their knowledge, behaviour, attitudes, and beliefs toward infection control measures need to be improved by problem-based training and multimodal and multidisciplinary approach.

Abstract ID: 2800

Achieving hand hygiene at blood collection sessions: Scottish National Blood Transfusion Service

Ann Paterson1, Kathryn Dick2, Graeme Paterson2, Louise Anderson2
1Scottish National Blood Transfusion Service/ Health Protection Scotland
2Scottish National Blood Transfusion Service

Improvement Issue and Context
Following the introduction of the ‘WHO five moments for hand hygiene’ in 2007, increased use of alcohol based hand rub (ABHR) led to an increase in the number of reportable skin irritation incidents from donor services staff. The complex multi-processes involved in taking a blood donation meant that healthcare workers (HCWs) were performing hand hygiene up to ten times per donation, nursing approximately 30 donors per session. Donors are healthy individuals that carry normal skin flora. HCWs hand hygiene is primarily important to prevent contamination of the blood products collected. This project sought to address this without compromising donor care or the blood products collected.

Methods and Measurement
Two small studies were undertaken to compare the efficacy of hand hygiene when following the ‘five moments for hand hygiene’ against risk assessed stages of the blood collection procedure i.e. performing hand hygiene only immediately before haemoglobin testing, immediately prior to venepuncture and immediately before needle removal.

Whilst HCWs followed the standard protocol, hand hygiene practice was observed; finger dabs ascertained the level of bacteriological counts from HCWs. The results showed there was a marginal reduction in bacteriological counts when the study protocol was undertaken. SNBTS obtained agreement through Clinical Governance structures to implement the proposed change to use ABHR in line with the study protocol.

Evidence of Improvement
HCWs at donor sessions have been implementing the study protocol since February 2013; there has been a reduction in staff skin irritation reports from 7 in 2012-3 to 1 in 2013-14. Furthermore, the finger monitoring data has shown no change since the introduction of the hand hygiene protocol. There have been no reports of contaminated blood products.

Future Steps
Staff are encouraged to continue reporting any incidence of skin irritation and overall quality control of hand hygiene continues.
of new novel ways of education. One method, soon to be trialled, is IC nurses working alongside healthcare professionals on a ward, providing senior nurse support and education at the very place it matters the most.

Abstract ID: 2863

Findings from a health education outreach intervention covering hygiene and the spread, treatment and prevention of infections

Authors: Beverley Hoekstra, Vicki Young, Cliodna McNulty
Public Health England Primary Care Unit

Improvement Issue and Context

Antibiotics are the most commonly prescribed childhood medicine, and in much of Europe, antibiotic prescribing rates are highest in children (Spyridis & Sharland, 2008). Within schools, infections are a major cause of childhood illness and absenteeism, with poor respiratory and hand hygiene contributing to increased absenteeism, with poor respiratory and hand hygiene contributing to increased spread. During the 2011/12 academic year “illness (not medical or dental appointments)” accounted for the majority of student absenteeism (Department for Education, 2013).

e-Bug educates young people about microbiology, hygiene and the spread, treatment and prevention of infection. The e-Bug resources comprise of educational packs for teachers and an interactive website. An outreach project is underway to determine how the e-Bug resources can be used by a broader audience, including school nurses and informal educators.

Methods and Measurement

To determine how e-Bug can assist other individuals, qualitative focus groups and interviews are being conducted with school nurses, school nurse assistants, teachers, and other stakeholders. Research is underway in Gloucestershire, Leicestershire, Shropshire and London. The health education role of informal educators is being explored, along with resource and training needs.

Evidence of Improvement

Preliminary data identifies that e-Bug should be targeted at various informal educators, and in some regions school nurses. Our research indicates the school nurse’s role varies significantly across localities. The provision of health education by school nurses, including education on hygiene and infection related topics, also varies greatly. Findings from this research will be presented, along with plans for tailoring or designing new educational resources.

Future Steps

These findings come at a time when the Department of Health’s UK Five Year Antimicrobial Resistance Strategy identifies a key area for future action as improving professional education, training and public engagement (Department of Health, 2013). This research has implications for all practitioners involved in educating the public about infection related topics.

Abstract ID: 2880

Leadership training for infection prevention practitioners

Sarah Freeman1, Elaine Ross2
1NHS Education for Scotland, 2NHS Dumfries and Galloway

Service Improvement

Infection Prevention and Control Practitioners (IPCPs) are challenged by the increasing demands on their expertise and skills as organisations combat healthcare associated infection. As Leaders, they have to focus on targets, managing tensions between innovation, governance and engaging and enabling others to succeed. This can be challenging and therefore requires a model of engaging leadership.

Methods and Measurement

In 2013, IPS (Scottish Branch) tendered for an individual or organisation to provide a leadership training programme for 10 IPCPs, utilising action learning and 360 degree appraisal. The IPCPs agreed the 5 success criteria at the start of the course and an evaluation questionnaire was completed.

Results

It was important for the group that they were comfortable in role and felt secure to discuss challenges facing them in the workplace and move forward. One IPCP described how the course helped her “prepare for a new senior position”. Practitioners described how the course made confident and effective IPCP by exploring their attributes and the valuable contribution made in the workplace. As a result of the course the IPCPs became more assertive saying they would “network more” and have “the confidence to take different opportunities”. Reflective practice is an important learning opportunity. IPCPs comments included that the course “taught me not to pre-judge and to be more open-minded” and to focus on “positive reflection”. Impact of the service is important and IPCPs described how other members in their team could see the benefits.

Discussion

The Facilitator described the participants as “hungry to learn” and there was a high level of engagement. Since completing the course 3 of 10 IPCP have obtained promoted posts. Future developments are to build in a workshop 6 months after the end of the programme to capture impact of learning and sustain growth.

Abstract ID: 2894

A survey for competency of certified nurses in infection control in Japan: Differences among novice, competent, proficient, and expert

Hanako Misao1, Kazumi Kawakami2
1Graduate School of Nursing, Miyagi University, Japan, 2Faculty of Health Care and Nursing, Juntendo University, Chiba, Japan

Introduction

In Japan, as of July 2013, 1808 nurses are registered certified nurses in infection control (CNICs) through Japanese Nursing Association (JNA). The goal of career development and a systematic educational program for CNICs have not been developed in Japan. It is necessary to develop a competency model for Japanese CNICs. Therefore, the purpose of this study was to identify CNICs’ competency status.

Methods

We conducted a cross-sectional study of CNICs’ competency in infection prevention practice using a self-administrated questionnaire of 5-point Likert scales based on a competency self-assessment tool developed by Association for Professionals in Infection Control and Epidemiology. The questionnaires were mailed to 1711 CNICs listed from JNA’s website. This study was approved by the IRB of Juntendo University.

Results

975 CI CN returned the questionnaire (57% response rate), of which the responses from 969 (99.3%) were used in the analysis. Based on the years of experiences as CI CN and working status, respondents were divided into 648 novice (66.9%), 201 competent (20.7%), 110 proficient (11.4%), and 10 experts (1.0%). The mean scores of core components of the questionnaire were as follows: identification of infectious disease process 17.1±6.9; surveillance and epidemiologic investigation 6.9±3.1; preventing/controlling the transmission of infectious agents 34.1±13.2; management and communication 26.4±11.1; education and research 26.4±11.1; and employee/occupational health 6.3±3.2. The percentages of scoring mean of each core components were from 44% to 48.9%. The percentages of four other components, which were “future-oriented domains”, were from 39.3% to 46.6%.
Conclusion
Because the majority of the respondents were novice and competent CICNs, the percentages of scoring mean of each components of competency were under 50%. Further, we have to identify the differences of each components of competency among novice, competent, proficient, and experts, in order to examine the career development and continuing educational system.

Abstract ID: 2896

Present conditions and issues surrounding certified nurse in infection control (CNIC) in Japan
Chie Umakoshi, Mr. Satoshi Fujinaga, Mr. Kakuei Oosaki, Yumiko Mizukami, Tomoko Sakihama, Sachiko Morishita, Yumi Matsushima, Chiyako Hirose
Infection Control Network of Japan (ICNJ)

Background
In Japan, the Japan Nursing Association (JNA) introduced the Certified Nurse Organization in 1995, and the educational system for the Certified Nurse in Infection Control (CNIC) was started in 2000. CNIC established the Infection Control Network of Japan (ICNJ) to enhance specialty among members in 2003. The Health Care Reform Act 2012 grants an assessment to hospitals that employ an infection control nurse and meet certain conditions. We report here the present conditions and issues surrounding CNIC which we found out throughout one of ICNJ main tasks, fact-finding, within its members.

Method
Diversified analysis on the data from the fact-finding among members registered in ICNJ

Result
The number of CNICs increased from 18, when the authorised system started in 1995, to 1,804 in 2013. The ICNJ membership also increased from 103 at the time of it establishment to 1,390, approximately 76% of CNIC. The number of full-time infection preventionists (IPs), dedicated to infection control and prevention, increased from 61% to 72% by the introduction of the Health Care Reform Act 2012. The Infection Control Program implemented throughout the year shows no significant changes over years in teamwork, rounding, and consultation. However, there was a gap in implementation of the surveillance between IPs dedicated to infection control and ones with multiple tasks.

Conclusion
The Certified Nurse Organization has educated many IPs in Japan. The Health Care Reform Act has been helping achieve full deployment of full-time IPs in all medical institutions. However, we should not overlook that a high level of Infection Control Program has not been accomplished due to several factors such as institutional circumstances and IPs’ experience. The role of ICNJ and its responsibility should be to support IPs so that they can fully serve patients with specialized knowledge and skills on a daily basis.

Abstract ID: 2899

In the patient zone: healthcare staff’s perceptions of the 5th Moment and implications for hand hygiene education
Lesley Price1, Lisa Ritchie2, Jacqui Reilly1, Jackie McIntyre2, Jon Godwin1, Donald Bunyan2
1Glasgow Caledonian University, 2Health Protection Scotland

Introduction
Hand hygiene is one of the most effective measures in preventing healthcare associated infection. The 5 moments for hand hygiene provides guidance on when hand hygiene should be performed. Compliance with the 5 moments is lowest for the 5th moment. The research aimed to evaluate healthcare staff’s perceptions of moment 5 for hand hygiene relative to compliance with this moment.

Methods
A mixed methods study was conducted using focus groups, non-participant observation and survey with focus groups informing the design of the questionnaire. The population was healthcare staff observed during three National Hand Hygiene Audits in three Scottish Health Boards. The purposive sample was staff observed who had an opportunity to perform hand hygiene in accordance with the 5th moment. Of the 484 participants observed 410 returned a questionnaire; a response rate of 85%.

Results
Results showed that hand hygiene compliance following the 5th moment was high with 93% of staff performing hand hygiene. Compliance varied with Health Board (χ²(2)=10.3,1p=0.006) but not professional group (χ²(2)=5.3,1p=0.2). Staffs’ perception of the 5th moment were positive with over 65% indicating that it was clearly defined, achievable, valuable, encouraged, widely known and not too time consuming. Participants were less positive about the repetitive nature of the 5th moment with 60% indicating that it was repetitive. There was a positive relationship between compliance and the perception that the 5th moment was widely known (Mann-Whitney U 2p <0.001).

Discussion
Although staff were generally positive about the 5th moment hand hygiene compliance was not optimum. Lack of understanding of the guidelines regarding the implementation of the 5th moment may be contributing to staffs’ perception that it is repetitive. There provides an opportunity to improve compliance by focusing education to raise awareness of the 5th moment and how it should be implemented in practice.

Abstract ID: 2939

Don’t be a Bug Rug - engaging children in infection prevention
Josephine Keward. Vicky Charnock
Alder Hey Children’s NHS Foundation Trust

Improvement issue and Context
Alder Hey Children’s NHS Foundation Trust provides care for babies, children and young adults. Information is widely available on Infection prevention topics for adult patients but there is a lack of child friendly patient information available in a format that children are able to understand.

The Infection Prevention Team worked with the Trust Arts for Health Co-ordinator. Patient information lead and a Children’s author to produce a child friendly booklet about the infections that are common in a Paediatric Hospital.

Methods and Measurement
The Infection Prevention Team provided a Children’s author with information and descriptions and photographs of commonly occurring pathogens in a Paediatric Hospital. The organisms chosen were RSV, Influenza, Rotavirus, Norovirus, MRSA, Chickenpox and ESBL. A children’s author Hilary Keating worked with children who were inpatients at the hospital to produce illustrations, stories and poems. Hilary collated these in a book “Don’t be a Bug rug”. The Infection Prevention Team reviewed all the stories to ensure that the Infection prevention messages were accurate. The completed books were produced with laminated pages and were spiral bound so that they could be easily cleaned.

Evidence of Improvement
The child friendly books were distributed to the clinical areas for use by the Nursing staff, parents and Play leaders. Stories from the book have now been turned into animations by Twin Vision a multi -media charity. Children were involved in all stages of the process from making the puppets to filming. The Infection Prevention Team achieved Investors in Children Status for their involvement in the project.

Future steps
Having identified the benefits of working with patients to provide information in a format that they can understand, we are now involving our patients in all our forthcoming educational campaigns.
Abstract ID: 2959

Making hand hygiene child’s play!

Kate Bickerstaffe¹, Denise Boyle¹, Julie Sellers¹, Pat Tyler², Alan Watson³
¹Alder Hey Children’s Foundation Trust, ²JT0 Photography, ³Vocalbooth

Improvement issue and context
The importance of hand hygiene to prevent the spread of infection has long been established. The World Health Organisation (WHO) identifies 5 key moments when hand hygiene is required. The Infection Prevention & Control Team (IPCT) was looking for a novel way to ensure not only staff, but children and their caregivers were aware of, and could remember all “5 Moments”.

Methods and Measurement
The IPCT wrote lyrics, set to the tune of “Magic Moments”, and a storyboard for an accompanying video was designed. Copyright was obtained and the song produced by a local sound engineer incorporating the voices of children attending clinic. The Trust Forum children and their parents were then spoken to about the video project. All children approached agreed to take part in the making of the video; some acting, some making costumes and others working behind the camera. Children attended on two Saturdays. The first day was spent talking about bugs and the “5 Moments”; discussing the proposed storyboard; designing and making costumes and assessing their Ayliffe technique using the UV light box. Shooting the video took place on the second day and a third and final day was spent capturing examples of the “5 Moments” throughout the Trust featuring a variety of staff, patients and their families.

Evidence of improvement
The children involved gained awareness of the “5 Moments” and had fun doing so. By producing a format other than written information, we have broadened our audience to include very young children and people for whom literacy is an issue.

Future Steps
Once the video is completed, it will be uploaded to the Trust website and social media accounts.
Epidemiology and surveillance of HCAI

Abstract ID: 2803

First community cluster of New Delhi Metallo-beta-lactamase-1 (NDM-1) Escherichia coli in Scotland

Josie Murray, Nigel Calvert, Linsey Batchelor, Martin Connor, Elaine Ross, Andrea Whelan

NHS Dumfries & Galloway

Introduction

We report a cluster of urinary tract infection caused by New Delhi Metallo-beta-lactamase-1 (NDM-1) Escherichia coli in the community between August and November 2013. There have been 12 Scottish isolates of this organism since 2007, mostly associated with acute settings, so the occurrence of three community infections in a small geographical area is of public health significance.

Methods

All cases were identified by the local clinical diagnostic laboratory. Surveillance was increased in the local laboratory, and suspicious isolates were promptly dispatched to the reference laboratory. Cases were investigated epidemiologically. Since no specific questionnaire was available for CRE community outbreaks, a new form was adapted from the existing PHE acute questionnaire. Enhanced surveillance of catheter urine specimens was continued until January 31st but identified no further CRE isolates.

Results

Epidemiological investigation revealed links between cases: a locum doctor; the Out-Of-Hours care; and a local dental surgery. Microbiologically, final reporting concluded that the isolates belong to a cluster of NDM producers from diverse geographical locations, suggesting that it represents a successful international lineage.

Discussion

It is clinically significant to have a community cluster of this rare organism in Scotland. We hypothesise this cluster may represent the spread of the problem from England into Scotland. We also highlight that attendance at dental surgeries and community healthcare facilities may be an under-recognised route for the spread of infections such as these. Prompt and thorough environmental decontamination, combined with education of staff in community healthcare settings is important to prevent further infection, however this alone is insufficient. Continued surveillance efforts are critical to ensure early detection and alternative methods of treating infection must be contemplated. Antibiotic stewardship is vital in limiting the spread of these highly resistant organisms. Regulation of antibiotic use in agriculture should be considered. Development of new classes of antibiotics is required.

Abstract ID: 2809

Findings from mandatory surveillance of Escherichia coli bloodstream infections in the West Midlands, England, 2012-2013

Shakeel Suleman1, Obaghe Edeghere1, Sabine Bou-Antoun2, Tom Fowler1


Introduction

Escherichia coli (E. coli) bacteraemia is an important healthcare associated infection (HCAI) which laboratory reports have shown has been increasing. Mandatory surveillance was introduced in June 2011. We described and compared the epidemiology of E. coli bacteraemia in the West Midlands against that of the rest of England during 2012-2013.

Methods

Data on all cases were obtained from the mandatory surveillance system. Categorical variables were summarised as counts and proportions with p-values for differences. Cumulative incidence and 95% confidence intervals were calculated.

Results

During 2012/13, 7101 episodes of E. coli bacteraemia were reported in the West Midlands representing 11% of all reports in England. The cumulative incidence was 126 per 100,000 population (95%CI 123.129) and 123 per 100,000 (95%CI 122, 124) in England, with similar distributions for age and sex.

The most common primary loci of infection (available data, n=4,808 cases) were urinary tract (44%), unknown sources of infection (26%), and hepatobiliary system (13%). These proportions were significantly different (p<0.05) from those in the rest of England, although the ranking of these sources remained unchanged.

The clinically assigned likelihood (completed for n=4,969 cases) that an episode represents a “likely” or “possible” HCAI was 27%. This was significantly different from the rest of England where it was 22% (p<0.001).

Discussion

Estimates of primary loci of infection and clinical likelihood of HCAI were different in the West Midlands compared to the rest of England. Further work is needed to understand the key drivers for infection and identify effective prevention measures.

Abstract ID: 2825

Pseudo outbreak of Kluyvera ascorbata Infections

Chin-Lu Chang, Yi-Chu Lo, Chao-Tai Lee

Tainan Municipal Hospital, Tainan, Taiwan

Introduction

Kluyvera ascorbata, famous for chromosome carrying blaCTX-M genes, was never isolated in Taiwan before. Even this organism is still rarely detected in medical practice till now. However, in a regional hospital in southern Taiwan, a strain of K. ascorbata was isolated from bile of one patient with acute cholecystitis on 17 March 2014. Thereafter, another strain of K. ascorbata was isolated from urine of another patient with urinary tract infection on 17 April 2014 at the same intensive care unit. We thought that this event was very unusual; hence, this study was conducted to investigate whether outbreak of K. ascorbata infections had occurred.

Methods

Pulse-field gel electrophoresis (PFGE) was used for bacterial typing. PFGE patterns were interpreted as follows. Two isolates were considered as the same strains if they had three or less band differences, and considered as the distinct strains if they had four or more band differences.

Results

PFGE patterns revealed that the two isolates of K. ascorbata had more than four band differences indicating that they were distinct strains.

Discussion

In this study, we proved that this was a pseudo outbreak of K. ascorbata infections. Herein, we must warn that an outbreak should be highly suspected if two or more rare organisms of the same species are isolated successively, especially from the same medical unit.
Abstract ID: 2834

The association between Central line-related bloodstream infection (CLABSI) and catheter-related bloodstream infection (CRBSI) according to various organisms

Chao-Tai Lee, Mei-Lien Fang, Chin-Lu Chang, Pei-Yu Su
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Introduction
Diagnosis of catheter-related bloodstream infection (CRBSI) requires specific laboratory evidences. A simpler definition, central line-associated bloodstream infection (CLABSI), is recommended for surveillance purposes. To our knowledge, a few studies have reported that the positive predictive value (PPV) of CLABSI for CRBSI was less than 50%. In this study, we attempted to explore that according to various organisms.

Methods
A retrospective study was performed at a regional hospital in southern Taiwan from September 2012 to March 2014. Of all CLABSI cases collected by infection control practitioner, only those with catheter tip culture were enrolled, and the remaining cases were excluded. CRBSI was defined as the identification of same organisms from the paired blood and catheter tip cultures (≥ 15 colony-forming units) without evidence of secondary bacteremia from other infection sources.

Results
Overall, 82 organisms from 73 CLABSI cases and 35 organisms from 35 CRBSI cases were collected and analyzed. According to the CLABSI cases, the PPV for CRBSI was 47.9% (35 of 73). According to the causative organisms, that was 82.4% (14 of 17) in S. aureus, 40% (4 of 10) in CoNS, 60% (6 of 10) in P. aeruginosa, 8.3% (1 of 12) in Enterobacterciae, 58.3% (7 of 12) in Candida, and 14.3% (3 of 21) of other organisms.

Discussion
In this study, we found that the PPV of CLABSI for CRBSI varied with different causative organisms from 8.3% (Enterobacterciae) to 82.4% (S. aureus). The three organisms, including S. aureus, P. aeruginosa, and Candida, had a higher PPV (≥ 58.3%); hence, if the causative organisms of CLABSI cases are these three organisms, the diagnosis of CRBSI should be highly suspected. By contrast, if the causative organisms are other organisms, CRBSI are less likely; hence, further laboratory studies may be necessary to diagnose CRBSI.

Abstract ID: 2850

Utility of community combined with hospital data to explain local variations

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Introduction
Norovirus impact in NHSScotland is assessed by Health Protection Scotland (HPS) undertaking a weekly point prevalence of closed wards. Norovirus season 2013-2014 was exceptionally quiet in Scotland, however, concern was raised in NHS Borders as impact seemed to be on a par with previous years. NHS Borders sought reassurance that hospital norovirus outbreaks were being introduced primarily from the community.

Methods
A review of available data was undertaken to compare: Wards closed in NHSScotland and NHS Borders against a 5 year average. The highest numbers of ward closures over multiple seasons, and Calls to the national helpline NHSS24 related to ‘diarrhoea’ and ‘vomiting’ from NHSScotland and from NHS Borders against a historical average.

Results
A total of 6819 samples, mostly obtained from sputum, were enrolled in this study. The detectable rate of TBC was 5.8 % (n = 394), and 3.9% (n = 269) by using Biochip, TCM, and AFS, respectively. In addition, 510 (7.5%) and 473 (6.9%) NTM were also detected by Biochip and TCM, respectively. Of all the samples, 460 had positive result by AFS; the accurate rate of identifying TBC by AFS was 58.5% (269 of 460).

Discussion
As a result of this study, the detectable rate of TBC was similar between Biochip, a rapid method (less than 24 hours), and TCM, a time-consuming method. In addition, Biochip had a higher detectable rate of TBC and cannot differentiate between TBC and non-tuberculosis Mycobacterium (NTM). Although TCM is regarded as the golden standard of identifying TBC, it is a time-consuming method. The aim of this study was to evaluate the role of identifying TBC by Biochip (DR.Chip Biotech, Inc., Taiwan), a quick diagnostic molecular method.

Abstract ID: 2869

The application of Biochip to identify Mycobacterium tuberculosis complex

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Chi-Mei Medical Center, Tainan, Taiwan

Introduction
Mycobacterium tuberculosis complex (TBC) can result in nosocomial outbreak, especially in the setting of delayed diagnosis. Traditionally, acid-fast stain (AFS) and traditional culture method (TCM) are used to identify TBC. However, AFS has a lower detectable rate of TBC and cannot differentiate between TBC and non-tuberculosis Mycobacterium (NTM). Although TCM is regarded as the golden standard of identifying TBC, it is a time-consuming method. The aim of this study was to evaluate the role of identifying TBC by Biochip (DR.Chip Biotech, Inc., Taiwan), a quick diagnostic molecular method.

Methods
This was a retrospective study at Chi-Mei medical center in southern Taiwan. From January to December 2013, all clinical samples sent for identifying TBC were enrolled in this study. Three methods were used to identify TBC, including Biochip, TCM, and AFS.

Results
A total of 510 (7.5%) and 473 (6.9%) NTM were also detected by Biochip and TCM, respectively. Of all the samples, 460 had positive result by AFS; the accurate rate of identifying TBC by AFS was 58.5% (269 of 460).

Discussion
As a result of this study, the detectable rate of TBC was similar between Biochip, a rapid method (less than 24 hours), and TCM, a time-consuming method. In addition, Biochip had a higher detectable rate and more accurate rate than AFS (5.8% vs. 3.9% and 100 % vs. 58.5%, respectively). Hence, we consider that Biochip should have an important role to identify TBC, resulting in rapid diagnosis and treatment of tuberculosis as well as decreasing nosocomial spread.

Abstract ID: 2882

Multi-disciplinary approach to reducing Surgical Site Infection following cardiac surgery

Lisa Butcher, Sayeed Rana, Mario Petrou, Lily O’Connor, Sarah Malone, Calum Buchanan
Oxford University Hospitals

Introduction
A retrospective audit was conducted to assess minimum surgical site infection (SSI) following cardiac surgery because of anecdotal observations of increased impact showed that at no time were more than 2 wards closed in the acute hospital during 2013-2014. Compared to the historical average, NHSS24 data showed that NHSScotland had fewer calls for help with ‘vomiting’ whilst NHS Borders’ calls for ‘diarrhoea’ and ‘vomiting’ were on par with previous years, with several peaks noted.

Discussion
NHSS24 data on calls on ‘diarrhoea’ and ‘vomiting’ during winter is likely to be mainly due to norovirus. This is the first time NHSS24 calls data has been used as an adjunct to the HPS prevalence data – this confirmed a local community norovirus issue. NHS Borders could reassure their community that multiple data sources supported the premise that the norovirus outbreaks in the hospital were the result of repeated introductions from the community and not a continuous hospital outbreak. Additional work is needed to explore the utility of NHSS24 calls in reducing the incidence and impact of norovirus.
infection rates. The audit reviewed all cardiac surgery patients from July 2010-August 2012 and identified a minimum rate for deep incisional SSI and organ/ space of 2%. An action plan was developed to improve clinical practice for the prevention and monitoring of SSI.

Methods
Procedures were reviewed in accordance with guidelines for the prevention and treatment of SSI (NICE, 2008), including pre and post-operative skin/nasal/mouth decontamination, peri-operative antibiotic prophylaxis, best practice for intra-operative care and wound management. Endoscopic vessel harvesting was established. Compliance with standards were audited and reported monthly.

An advanced nurse practitioner was appointed to conduct prospective SSI surveillance and monitor compliance with SSI prevention policies and guidelines. Wounds are monitored regularly for evidence of infection through observation, review of medical/nursing notes, observation charts and microbiology liaison.

All suspected deep incisional or organ/space infections are discussed at multidisciplinary team meetings to conduct root cause analysis and agree infection classification according to Public Health England definitions.

Results
From April 2013 to March 2014 the rate of deep incisional and organ/space infection has been reduced to 1%.

Discussion
Improvement in patient outcomes and a reduction in the rate of deep incisional and organ/space infection have been achieved through a variety of interventions. Incidents of SSI are reported to clinical governance. Learning from case review meetings is disseminated to continue to the reduction in the rate of SSI after cardiac surgery.

Abstract ID: 2887

**Comparison of caesarean section Surgical Site Infection post discharge surveillance methods, within NHSScotland**

Christopher Sullivan, Jane McNeish, Laura Imrie
Health Protection Scotland

Introduction
The Scottish Surveillance of Healthcare Associated Infection Programme (SSHAIP) within Health Protection Scotland (HPS) coordinates the surgical site infection (SSI) surveillance programme in NHS Scotland. All NHS boards are currently required to undertake surveillance for caesarean section procedures as per the mandatory requirements. Post discharge surveillance (PDS) until day 10 post operatively is carried out for all caesarean section procedures. The proportion of caesarean section SSI detected by PDS to day 10, not including inpatient infections, accounted for 85.3% of all the SSI detected for caesarean section during 2013 within NHSScotland. A review of the methods used to collect caesarean section PDS data was conducted by HPS in 2014 to ensure consistency and comparability between NHS boards.

Methods
SSI surveillance in NHS Scotland is conducted according to the SHSAIP protocol, with adherence to the definitions for SSI. Data are collected prospectively on eligible patients from the time of surgery to discharge, death or 10 days for caesarean section post operatively, whichever occurs soonest. A telephone questionnaire on PDS methods was conducted by HPS with a surveillance coordinator from each of PDS methods was conducted by HPS with a surveillance coordinator from each of the patient population and that data presented in the public domain are accurate thus ensuring comparability between NHS boards.

Abstract ID: 2892

**Transmission dynamics of Methicillin-Resistant Staphylococcus aureus on an acute care medical unit**

Simon Lai1, Elisa Lloyd-Smith2, Nienke Van Houten1, Marc Romney2
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Introduction
Factors affecting the transmission of healthcare-associated infections in hospitals, including Methicillin-Resistant Staphylococcus aureus (MRSA), are poorly understood. Using a micro-epidemiological framework typically applied to vector-borne diseases, we examined the transmission dynamics of MRSA on a medical unit of an acute care hospital in Vancouver, Canada.

Methods
We calculated the basic reproductive number (R0) and the relative impact of infection control interventions from 1 June to 31 July, 2013 (medical unit size, n=125 beds). Interventions included: nursing-patient contact, hand hygiene compliance and contact precaution. Patients with laboratory confirmed MRSA were identified by an electronic flag in our patient management system.

Results
The estimated basic reproductive number for MRSA was 0.37 without compliance to hand hygiene and 0.12 without compliance to contact precaution. The effective reproductive number was reduced to 0.07 when all infection control measures were included. The impact of infection control interventions reduced the prevalence from a predicted 17% to an observed 13%. Under the circumstances tested, MRSA was stabilized primarily by the constant introduction of patients previously known to be MRSA-positive.

Discussion
MRSA persistence on our medical unit was found to be associated with the high prevalence of MRSA in the population served by the hospital. Future investigations and implementation of infection control strategies need to take into consideration local epidemiology.

Abstract ID: 2911

**A Review of E. coli bloodstream infections in a large teaching hospital**

Andrew Letters, William Ogbum, Dan Wilson, Ogra Marufu
King’s College Hospital NHS Foundation Trust

Introduction
A review of Escherichia coli (E. coli) bloodstream infections diagnosed from May to November 2013 across the medical division at a large London teaching hospital was undertaken. The aim was to establish the predisposing risk factors, inform and improve practice.

Method
A total of 17 patients with E. coli positive blood cultures were reviewed. The patients’ clinical records were examined to establish if these patients had any of the following predisposing risk factors: urinary catheter (UC), vascular access device (VAD), other invasive/indwelling device(s), surgical, other invasive procedure, neutropenia and wounds/ulcers. The management of these patients was measured against the Trust best practice guidance to identify any breaches in care protocols.
Results
All 17 patients had one or more predisposing risk factors. Sixteen patients had a VAD. 12 had an indwelling UC. 11 had both UC and VAD and 6 of the patients had wounds prior to the positive blood culture. The care of all the patients' VAD and wounds was well documented in the clinical notes and this was taken as evidence of adherence to Trust best practice guidance on the care of VAD. Documentation of UC was generally poor.

Discussion
The predisposing risk factors identified in this cohort of patients were: indwelling VAD, UC and wounds. The Trust best practice guidance recommends accurate documentation of the care of VAD and UC. These results have prompted a review of how the medical division ensures this happens. For patients whom a UC is present or inserted, an electronic work order should be generated which nursing staff are required to complete. The documentation of all indwelling devices and wound care is now reviewed during the senior nurse rounds. Medical staff record the clinical need for indwelling devices as part of a structured ward round approach.

Abstract ID: 2918
Development of an outbreak tool to aid effective management of outbreaks in an acute hospital
Stephen Aplin1, Jacqui Prieto2, Julie Brooks1, Sue Dally1, Sarah Jeremiah1, Anne Schreiber1, Michelle Jones1, Vivienne O'Connor1, Graeme Jones1
1University Hospital Southampton NHS Foundation Trust, 2University of Southampton

Improvement Issue and Context
Effective and timely management of outbreaks, including accurate record keeping, is crucial to minimise the transmission of infection across wards within an acute hospital. Prior to 2011 our approach to outbreak management involved a paper form to gather information on symptomatic patients. The requirement to update information at least daily resulted in multiple paper forms per ward, which had the potential to be misplaced. Documentation was further complicated by the need to record patient moves and changes in symptoms. This paper system proved time consuming and caused inaccuracies.

Methods and Measurement
An outbreak management tool was developed using Microsoft Excel. Excel was chosen for its extensive range of formulae and availability across the Trust IT network. The tool mirrors the appearance of the original paper template but is able to calculate patient symptom timescales, which in turn shows when it is possible to re-open a ward. An ongoing record of advice from the Infection Prevention Nurse is maintained for ready reference.

Evidence of Improvement
The tool has delivered key benefits in collating and communicating accurate and timely data. It shows clearly the ward closure status and the infection status of individual patients. It is accessible via a tablet PC, enabling data entry on the ward. Information from the tool, including the total number of patients and staff infected, the number of wards affected and the total lost bed days is disseminated to key staff in the Trust by means of a daily summary report.

Future Steps
We plan to refine the tool and link it to the Microsoft Access database used by the Infection Prevention Team to record routine clinical activity. This will enable transfer of data from the tool to the main database to produce automatic final outbreak reports and avoid duplication of effort.

Abstract ID: 2932
Sampling cyclone and the collection of respirable pathogens
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Introduction
Sampling cyclones are powerful tools with which to capture bioaerosol material and the initial aim of this study is to assess the potential of sampling cyclones to collect respirable pathogens from within hospital environments. To achieve this aim the separation grade efficiency of the cyclone must be modelled in order to determine the size of particles that can be collected.

Methods
The operating conditions and dimensions of the cyclone influence the separation grade efficiency, whereas cyclone models and computational fluid dynamics (CFD) are used to determine this efficiency. This study chose four established models in addition to using validated numerical modelling techniques, to predict the separation grade efficiency of a 70 mm diameter glass sampling cyclone.

Results
The modelling of the cyclone operating at 600 l/min predicts that there is a 100% probability of particles of between 3 – 6 microns and greater in size being successfully collected. The particle size captured with 50% efficiency is estimated to be within the range of 1 – 2 microns, whereas particles below this range have a diminished chance of collection with decreasing size.

Discussion
Given that the respiratory spray from a cough or sneeze includes particles in a <1 to 500 micron range, the 70 mm diameter sampling cyclone is predicted to have the potential to collect 99% of this particle size range. The cyclone is also predicted to collect with 100% efficiency particles of 4 microns and airborne pathogens of this size have the potential to reach the respirable regions of the lungs. This study suggests that sampling cyclones offer the chance to investigate how the risks associated with airborne pathogen distributions, such as with influenza and norovirus, work in normal clinical practice in order that effective interventions at patient, environmental and building design level can be constructed.

Abstract ID: 2933
Alert organisms at a specialist Paediatric Trust 2011-2014
Josephine Keward
Alder Hey Children’s NHS Foundation Trust

Introduction
Paediatric patients can present unique challenges to an Infection Prevention & Control Team due to their susceptibility to infections prevented in older patients by previous exposure or vaccination. As a result the micro organisms causing healthcare associated infection (HCAI) in Pediatrics can be different to those affecting adult patients. This prospective study looked at the incidence of alert organisms at a specialist Paediatric Trust and identified those organisms identified as causing HCAI and being responsible for outbreaks of infection over a 3 year period.

Methods
Alert organisms identified in the laboratory were entered into a database on a daily basis by the Infection Prevention & Control Nurses. Data for the 3 year period from April 2011- March 2014 was reviewed. Agreed definitions for nosocomial infection were applied to the data.
Results
Incidence of Hospital acquired MRSA colonisation and infection were low during the 3 year period. Outbreaks of MRSA were associated with long stay patients with multiple indwelling devices. The incidence of Clostridium difficile associated disease was very low and limited to the Oncology unit. CLABSI were a significant cause of HAI. Significant numbers of MSSA bacteraemia were identified during the 3 year period. Multidrug resistant organisms such as ESBL producers and CPE led to outbreaks in high risk areas. The admission of large numbers of patients with viruses such as RSV and rotavirus during the winter and early spring each year place considerable pressure on the isolation facilities and staff workload and each year a number of HAI were identified. Exposure to childhood illnesses such as Chickenpox and Measles led to nosocomial infection in unvaccinated children.

Discussion
Nationally set targets fail to address the frequent causes of HCAI in a Paediatric Trust. Local targets should be set to target the causes of HCAI within Paediatrics.

Abstract ID: 2938

An outbreak of an Extended Spectrum Beta lactamase (ESBL) producing Escherichia coli in a Neonatal Surgery Unit
Josephine Keward
Alder Hey Children’s NHS Foundation Trust

Introduction
Between May-July 2013, 12 babies were identified as having acquired an extended spectrum B-lactamase (ESBL) producing Escherichia coli on our 12 cot neonatal surgical unit. Eight babies had rectal colonisation and four developed clinical infection. One baby subsequently died as a result of E.coli sepsis. The unit had limited isolation facilities and babies colonised with ESBL frequently were nursed in the open ward. Clinical procedures commonly undertaken included stoma recycling and bowel washouts which could easily contaminate the ward environment with bowel flora.

Interventions
The unit was closed to admissions after an initial outbreak meeting. The babies were moved to a vacant ward to allow HPV fogging and remedial building work to be undertaken. Swabbing of the environment and patient equipment and the wearing of PPE by staff and parents. All babies were nursed under strict contact precautions (long sleeved gowns / gloves) if identified as carrying an ESBL. Babies remained under contact precautions if their surveillance screens were negative. Education was provided to staff and parents on hand hygiene after audits identified that compliance with WHO 5 moments of hand hygiene was poor. A parent safety card was introduced to provide the parents with infection prevention guidance on their baby’s admission to the unit.

Results and Discussion
The outbreak was declared over when no more cases had been identified for 1 month. The interventions introduced during the outbreak have been continued without modification. The NSU moved back onto a refurbished unit at the end of October 2013. The capacity of the unit was reduced to 9 cots including 5 single rooms and staffing levels were increased to reflect a high dependency unit (1:2). There have been no further cases of the outbreak strain identified.

Abstract ID: 2953

Psychiatric disorders, psychotropic treatments and Clostridium difficile infection
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1Universidad De La Laguna, Canary Islands 2Hospital Universitario De Canarias, Canary Islands

Introduction
Previous research has suggested that the use of psychiatric drug treatments increases the risk of developing Clostridium difficile infection (CDI). The aim of this study was to assess the presence of intrinsic and extrinsic risk factors for CDI, paying special attention to the presence of psychiatric disorders and their treatment.

Methods
A retrospective cross-sectional descriptive study was carried out at the Hospital Universitario de Canarias (HUJC) Microbiology Service in the period 2009-2013.

Results
A total of 127 episodes of CDI corresponding to 122 patients were identified. Of these, 12 had at least one recurrence within the same episode. Mean age was 63 years. Prevalence rates of CDI increased from 0.34 to 1.81 cases per 1,000 hospitalised patients from 2009 through 2013. Temporal-spatial case study did not identify the presence of outbreaks. The average length of stay of patients prior to the development of infection was 21.2 days. The vast majority (71.9%) of the episodes were of nosocomial origin. Almost all the patients (98.5%) were using antibiotics prior to the development of the CDI, being the average number of 2.4 antibiotics per patient. Carbapenems were the most prevalent antibiotics (45.3%) used. Nearly half of patients (44.5%) suffer from psychiatric disorders, particularly depression and anxiety, using 39% of them benzodiazepines and 32% antidepressants, mainly selective serotonin reuptake inhibitors. Metronidazole and vancomycin were the most used drug treatment for CDI. Although 10 of the patients died during admission, it was not possible to relate in any of the cases the cause of death with the episode of CDI.

Discussion
The incidence figures recorded are relatively low compared with those published in similar healthcare devices. although there is a clear trend of increase. Our findings support the psychiatric disorders and their treatment risk factors listed in the literature.

Abstract ID: 2964

Epidemiology of nosocomial secondary bacteremia to other infectious processes in a Tertiary Hospital
Laura Sante, María Leucuona, María Antonia Miguel, María José Ramos, Yanet Pedroso, Zaida Díaz, Ana Madueño, Rocío Kohan, Milagros Cuervos
Hospital Universitario de Canarias

Introduction
Although many studies have already investigated epidemiology and risk factors related to Primary and Central-line associated Bloodstream Infections (BSI), knowledge of Secondary BSI to an infection at another body site is very limited. Our study aimed to investigate the epidemiology of Nosocomial Secondary BSI at a 66 bed tertiary hospital.

Methods
Retrospective and observational study of patients diagnosed of Nosocomial Secondary BSI during 2009-2013, following the 2008 CDC criteria. The medical records of these patients were retrospectively reviewed. We analyzed epidemiological and microbiological data.
**Results**

**Table 1.**

<table>
<thead>
<tr>
<th>Total BSI (N)</th>
<th>Total</th>
<th>2° BSI (N)</th>
<th>2° BSI (%)</th>
<th>Total</th>
<th>Microorganisms*</th>
</tr>
</thead>
<tbody>
<tr>
<td>PRIMARY INFECTION</td>
<td>1633</td>
<td>345</td>
<td>21.13</td>
<td>130 (30.1%)</td>
<td>GPC</td>
</tr>
<tr>
<td>Respiratory tract</td>
<td>78 (22.22%)</td>
<td>85 (24.21%)</td>
<td>92 (26.21%)</td>
<td>26</td>
<td>S. aureus</td>
</tr>
<tr>
<td>Urinary tract</td>
<td>28 (7.98%)</td>
<td>43 (12.25%)</td>
<td>25 (7.12%)</td>
<td>28</td>
<td>NC Staphylococcus</td>
</tr>
<tr>
<td>Surgical site</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>69</td>
<td>Enterococcus spp.</td>
</tr>
<tr>
<td>Skin/Soft tissue</td>
<td>107 (32.6%)</td>
<td>85 (24.21%)</td>
<td>107 (32.6%)</td>
<td>10</td>
<td>Streptococcus spp.</td>
</tr>
<tr>
<td>Intra-abdominal</td>
<td>28 (8.48%)</td>
<td>43 (12.25%)</td>
<td>28 (8.48%)</td>
<td>62</td>
<td>GPB</td>
</tr>
<tr>
<td>Other</td>
<td>41 (11.45%)</td>
<td>41 (11.45%)</td>
<td>41 (11.45%)</td>
<td>71</td>
<td>GNB</td>
</tr>
<tr>
<td>Service</td>
<td>114 (31.84%)</td>
<td>114 (31.84%)</td>
<td>114 (31.84%)</td>
<td>162</td>
<td>Enterobacteriaceae</td>
</tr>
<tr>
<td>Medical</td>
<td>89 (24.86%)</td>
<td>89 (24.86%)</td>
<td>89 (24.86%)</td>
<td>93</td>
<td>NFGNB</td>
</tr>
<tr>
<td>Surgical</td>
<td>41 (11.45%)</td>
<td>41 (11.45%)</td>
<td>41 (11.45%)</td>
<td>3</td>
<td>Other</td>
</tr>
<tr>
<td>Intensive care unit</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>258 (61.1%)</td>
<td>YEAST</td>
</tr>
<tr>
<td>Hemato-oncology</td>
<td>25 (6%)</td>
<td>25 (6%)</td>
<td>25 (6%)</td>
<td>8</td>
<td>ANAEROBICS</td>
</tr>
</tbody>
</table>

*56 were polymicrobial infections.

GPC = Gram positive cocci
NC Staphylococcus = Coagulase negative staphylococci
GPB = Gram positive bacilli
GNB = Gram negative bacilli
NFGNB = Non-fermenting Gram-negative bacilli

**Discussion**

Secondary Bloodstream Infections are an important factor of morbidity and involve a rise in healthcare cost. They could be prevented with proper diagnosis and treatment to other infections.

**Abstract ID: 2965**

**The Incidence of oxacillin-resistant Staphylococcus aureus at a Regional Hospital in Southern Taiwan**

Chao-Tai Lee, Shiu-Yi Lu
Tainan Municipal Hospital, Tainan, Taiwan

**Introduction**

*Staphylococcus aureus* is an important pathogen in medical practice. Furthermore, oxacillin-resistant *Staphylococcus aureus* (ORSA) has increased difficulty in treatment. The incidence of ORSA is growing in some regions worldwide. Some interventions have been reported to decrease successfully the incidence of ORSA. In this hospital, contact precautions only are implemented as the infection control measure to decrease the incidence of ORSA. This study was conducted to explore whether this measure can reduce the incidence of ORSA in this hospital.

**Methods**

This was a retrospective study at a regional hospital in southern Taiwan. From 2007 to 2013, all *S. aureus* isolates obtained from blood cultures were enrolled in this study. If multiple isolates were identified from the same patient during the same hospitalization period, only the first isolate was enrolled. *S. aureus* were divided into oxacillin-susceptible *S. aureus* (OSSA) and ORSA.

**Results**

A total of 1,101 *S. aureus* isolates, including OSSA (n = 511, 46.4%) and ORSA (n = 590, 53.6%), were enrolled. The ORSA accounted for 57.1% (97 of 170), 53.3% (81 of 152), 53.3% (81 of 152), 57.1% (97 of 170), 48.1% (62 of 129), 43.6% (71 of 163), 51.3% (78 of 152), and 54.3% (94 of 175) of *S. aureus* in 2007, 2008, 2009, 2010, 2011, 2012, and 2013, respectively.

**Discussion**

As a result of this study, the incidence of ORSA was about 53.6% in this hospital, being higher in 2009 (66.9%) and lower in 2011 (43.6%). However, that seemed to remain constant during the 7-year follow-up period, indicating that contact precautions only were not sufficient to decrease the incidence of ORSA. Consequently, more effective infection control measures should be implemented to decrease the incidence of ORSA in this hospital.

**Abstract ID: 2967**

**Emergence and outbreak of OXA-48-producing Klebsiella pneumoniae in a Tertiary Hospital in Canary Island (Spain): epidemiology and control measures**

Ana Madueño, Lecuona Maria, Delgado Teresa, Diaz Zaida, Maria Antonia Miguel, Sante Laura, Pedroso Yanet, Maria Jose Ramos, Milagros Cuervo
Hospital Universitario de Canarias, Canary Islands

**Introduction**

The dissemination of carbapenemase-producing *Klebsiella pneumoniae* and the difficulty to treat its infections make it necessary to focus the efforts on infection control measures. Our aim was to describe epidemiological features and control measures of OXA-48-producing *K. pneumoniae* outbreak at a Spanish teaching hospital.

**Methods**

This was a retrospective study at a regional hospital in southern Taiwan. From 2007 to 2013, all *S. aureus* isolates obtained from blood cultures were enrolled in this study. If multiple isolates were identified from the same patient during the same hospitalization period, only the first isolate was enrolled. *S. aureus* were divided into oxacillin-susceptible *S. aureus* (OSSA) and ORSA.

**Results**

A total of 1,101 *S. aureus* isolates, including OSSA (n = 511, 46.4%) and ORSA (n = 590, 53.6%), were enrolled. The ORSA accounted for 57.1% (97 of 170), 53.3% (81 of 152), 53.3% (81 of 152), 57.1% (97 of 170), 48.1% (62 of 129), 43.6% (71 of 163), 51.3% (78 of 152), and 54.3% (94 of 175) of *S. aureus* in 2007, 2008, 2009, 2010, 2011, 2012, and 2013, respectively.

**Discussion**

As a result of this study, the incidence of ORSA was about 53.6% in this hospital, being higher in 2009 (66.9%) and lower in 2011 (43.6%). However, that seemed to remain constant during the 7-year follow-up period, indicating that contact precautions only were not sufficient to decrease the incidence of ORSA. Consequently, more effective infection control measures should be implemented to decrease the incidence of ORSA in this hospital.
Results
The outbreak of OXA-48-producing K. pneumoniae was detected between 10/19/2013 and 11/4/2013 in three patients admitted to general and digestive surgery unit, who coincided in time and space. Thus, infection surveillance, control and educational programs for healthcare workers, were conducted by the Infection Control Team. Active screening culture of rectal swabs was performed in all hospitalized patients at affected units. Patients colonized or infected were placed on contact precautions followed by chlorhexidine bathing.

Until 5/30/2014, 63 cases were reported: 23 (36%) in clinical sample (only or with a rectal swab) and 40 (64%) in rectal swabs. Out of the clinical samples, 15 (65%) were classified as nosocomial infections, 4 (17.5%) nosocomial colonizations and 4 (17.5%) extra-hospital infections (2 UTI and 2 bacteremia). Evolution of the incident cases is described in Table 1.

Discussion
This study showed a diminution of OXA-48-producing K. pneumoniae in clinical samples versus surveillance cultures. Our findings highlight the importance to implement prevention and infection control measures.

Abstract ID: 2972
Implementing surveillance of Surgical Site Infections in C-sections performed in an Acute Trust
Ryan George, Julie Cawthorne, Louise O’Connor
Central Manchester University Hospitals NHS Foundation Trust

Introduction
Saint Mary’s Hospital is a large tertiary referral centre serving the population of Central Manchester and patients with complex medical conditions referred from across the North West. As part of a service improvement exercise, the Infection Prevention & Control and Tissue Viability (IPC/TV) team conducted a programme of enhanced surveillance of Surgical Site Infections (SSI) following C-section deliveries with a view to incorporation into on-going SSI surveillance.

Aim
To determine a baseline rate for C-section SSI/identify associated risk factors in the population studied.

Method
With advice from the Surgical Site Infection Surveillance Service (SSISS) at Public Health England (PHE), data collection sheets, patient information and discharge letters/questionnaires were devised. Over a three month period, all elective and emergency C-sections were identified via theatre booking systems and surveillance forms were completed for each procedure on daily basis. A 30-day follow-up phone call was made to determine if there were any issues with wound healing, and criteria set forth by SSI surveillance were used to determine if the healing issues were true SSI.

Results
Of the 478 ladies who underwent delivery by C-section during the period of observation, follow-up data was obtained for 284 (59%). Using patient reported SSI classification criteria set forth by SSI surveillance, 71 ladies contacted were deemed to have experienced a SSI, representing 15% of the cohort studied.

Discussion
A baseline level of patient-reported C-section SSI has been established. Issues around data collection methodology and ownership were experienced and subsequently resolved. Whilst SSI surveillance following C-sections is mandatory in the rest of the UK, this is not the case in England. This study identified that useful data can be obtained once clear guidelines and protocols have been established. In addition to improving service provision and patient experience, significant financial savings can be made due to reduced readmissions and treatment costs.

Abstract ID: 2982
Prognostic indexes, length of stay and nosocomial infection in Intensive Care Unit: analysis of 835 cases From Brazil
Lilia De Souza Nogueira, Renata Eloah De Lucena Ferretti- Rebustini, Vanessa De Brito Poveda, Rita De Cassia Gengo E Silva, Ricardo Luis Barbosa, Kátia Grillo Padilha
University of São Paulo, Brazil

Introduction
Studies describing the occurrence of Infection Related to Health Assistance (IRHA) in the ICU and its relation to some selected predictive factors are lacking. We aimed to analyze the occurrence of IRHA in ICU, according to severity, length of stay (LOS) and nursing work load.

Methods
Cross-sectional study was done in 9 heterogeneous ICUs (clinical and surgical) belonging to a public hospital in São Paulo, Brazil, during 3 months. Data was collected from medical records of patients. Age, gender, LOS, occurrence of infection, number of infections per patient, admission criteria (clinical or surgical), prognostic indexes (SAPS II, Charlson, LODS) and the Nursing Activities Score (NAS) were analyzed. Non-parametric tests were used for the analysis and the Logistic Regression selected to enter the model all the variables whose p-value was ≥ 0.20. Data was considered significant when p ≤ 0.05.

Results
Sample was composed by 835 cases, mostly males (57.5%) with mean age of 54.26±17.29. IRHA was present in 12.5% of the cases (ranging from 1 to 8 events/patient). Among subgroup of IRHA patients, the occurrence of infection was more prevalent among male (8.4%; p<0.030), admitted for clinical treatment (8.1%; p<0.004). with a mean LOS of 6.98 days (p< 0.000). The number of infectious event was correlated to the LOS (r = 0.403, p<0.000), burden of disease measured by Charlson (r = 0.075; p<0.030), severity measured by SAPS2 (r = 0.182; p<0.000) and by LODS (r = 0.128; p<0.000). Age and NAS was not correlated to IRHA. By logistic regression, it was observed that LOS and SAPS2 prognostic score were independent related to the occurrence of IRHA.

Discussion
The increase in the LOS and the severity of the disease are associated to the risk of infection in ICU patients, despite the type of ICU or admission criteria.

Table 1

<table>
<thead>
<tr>
<th>Months</th>
<th>Nº clinical samples</th>
<th>Nº rectal swabs</th>
</tr>
</thead>
<tbody>
<tr>
<td>October 2013</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>November 2013</td>
<td>4</td>
<td>6</td>
</tr>
<tr>
<td>December 2013</td>
<td>4</td>
<td>10</td>
</tr>
<tr>
<td>January 2014</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>February 2014</td>
<td>5</td>
<td>6</td>
</tr>
<tr>
<td>March 2014</td>
<td>2</td>
<td>4</td>
</tr>
<tr>
<td>April 2014</td>
<td>2</td>
<td>4</td>
</tr>
<tr>
<td>May 2014</td>
<td>0</td>
<td>5</td>
</tr>
</tbody>
</table>

All of OXA-48-producing K. pneumoniae were CTXM-15 producers. Pulsed-field gel electrophoresis identified one main clone type.
Abstract ID: 2796

Knowledge, practice and attitudes of nurses towards infection control standards in West Bank governmental hospitals

Fady Zaben, Ahmad Abu Tayeh, Anis Al Hajjeh, Colin Green, Malik Zaben
International Medical Education Trust- Palestine (IMET2000-Pal)

Background
Adherence to infection control (IC) standards is a key component of nursing practice to reduce the rate of hospital-acquired infections. Low compliance with these standards has been reported in many developing countries. This study aims to explore the knowledge and compliance of nurses working in West Bank governmental hospitals with IC standards, in an attempt to guide future strategies to enhance these standards in Palestine.

Methods
A multi-centre, cross-sectional, descriptive study, using a self-administered questionnaire, was conducted in October-November 2013. Participants' knowledge and compliance regarding specific IC policies were sought and ranked on a scale of 9 (9 is the best score that can be achieved). Needs for training were also explored. SPSS was used for data analysis.

Findings
Of the total 175 nurses surveyed (from 8 hospitals), 54.9% were females, 77.1% had a bachelor degree or above and 72.6% had nursing experience of 5 years or more. According to our analysis, 53.7% had IC training inside the hospital and 80% reported the presence of IC nurse specialist in their hospitals. Respondents' knowledge of and compliance scores with IC standards were 7.44 and 5.23, respectively. Although there was an increase in knowledge scores with academic attainment, gender, years of experience and subspecialty, these had no significant effect on the scores. Interestingly, while previous in-hospital or outside hospital training had no effect on the scores of knowledge or compliance of participants, 97.7% indicated that infection control training is needed.

Interpretation
Education and training of healthcare personnel on IC standards are a prerequisite for ensuring that policies and procedures are understood and practiced. This study provides information about nursing IC practices in West Bank governmental hospitals. Results from this study are expected to guide efforts to develop educational programs to improve nursing IC practices in Palestine.

Abstract ID: 2799

Achieving the National Personal Protective Equipment Policy in Scottish National Blood Transfusion Service

Ann Paterson1, Joy Sinclair2
1Scottish National Blood Transfusion Service/ Health Protection Scotland,
2Scottish National Blood Transfusion Service

Improvement Issue and Context
The clinical apheresis service undertakes approximately 2,000 apheresis procedures and 2,000 other procedures such as therapeutic venesection or infusions annually. Following the implementation of the National Infection Prevention and Control Manual in September 2012, which states that 'gloves must be worn when exposure to blood or body fluids is likely/anticipated', the apheresis nurses highlighted that they were experiencing a significant amount of failed cannulation procedures. The nurses identified that whilst wearing gloves they were unable to clearly palpate the veins before cannulation. The aim of this study was to assess the benefits and risks.

Discussion
The adaptation has resulted in reduced number of failed cannulation attempts, which has reduced patients' pain/discomfort, reduced waste of sundries and reduced time spent on individual cannulations and improved staff satisfaction with their performance. No adverse events (staff exposures) have been reported. Staff are aware of the need to report any difficulties with implementation/cannulation policy to the Nurse Manager / Senior Nurse Infection Control.

Abstract ID: 2811

Understanding patients’ experiences of postoperative voiding difficulty and short-term urinary catheterisation following knee and hip replacement surgery

Jacqui Prieto1, Allison Willis2, Samantha Sartain1
1University of Southampton, 2University Hospital Southampton NHS Foundation Trust

Introduction
Urinary retention is a frequent complication following lower limb joint surgery. It is managed by urinary catheterisation (UC), introducing the risk of urinary tract infection. Little is known about patients’ experiences of postoperative voiding difficulty and catheterisation or their awareness of the associated risks. The aim of this study was to explore patients’ experiences and preferences relating to the management of voiding difficulty and UC following planned knee and hip arthroplasty.

Method
A qualitative study in the elective orthopaedic ward of a large teaching hospital was undertaken. Patients who underwent knee or hip replacement surgery were invited to participate in a semi-structured interview during their hospital stay. A purposive, maximum variation sample was used. Interviews were digitally recorded and transcribed verbatim. Inductive, thematic analysis was undertaken separately by two researchers.

Results
Eighteen interviews were undertaken, 10 following total hip replacement (5 women, 5 men) and 8 following total knee replacement (3 women, 5 men). Participants were aged 43-99 years (mean=70 years). 4 main themes were identified, each with subthemes (Table 1).

Discussion
Whether catheterised or not, most participants worried about toileting while in hospital and felt their dignity was affected. Six participants who had previously been catheterised said they preferred this, whereas 6 with no previous experience said they preferred to avoid having a catheter. Most patients reported no involvement in decision-making and said they received little or no information about benefits and risks.
Table 1. Interview themes and subthemes.

<table>
<thead>
<tr>
<th>Theme</th>
<th>Subtheme</th>
<th>Interview themes and subthemes.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Toileting</td>
<td>Using the toilet</td>
<td>Using the toilet</td>
</tr>
<tr>
<td></td>
<td>Using bedpans and uninals</td>
<td>Using the toilet</td>
</tr>
<tr>
<td></td>
<td>Changes to micturition</td>
<td>Using the toilet</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Worrying about access</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Discomfort</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Ease of use</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Over-filling</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Unable to void</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Urgency/frequency/flow</td>
</tr>
<tr>
<td>Having a catheter</td>
<td>Benefits versus risks</td>
<td>Benefits versus risks</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Convenience</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Comfort</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Piece of mind</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Embarrassment</td>
</tr>
<tr>
<td>Preference and choice</td>
<td>Involvement in decisions preferences</td>
<td>Provision of information</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Choice</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Catheter vs no catheter</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Informed by experience</td>
</tr>
<tr>
<td>Privacy and dignity</td>
<td>Loss of control</td>
<td>Wetting and spillage</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Dependency</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Coping with embarrassment</td>
</tr>
</tbody>
</table>

Discussion

Patients worry about toileting while in hospital and may have strong preferences relating to UC. The influence of previous experience of UC on future preference suggests preferences may alter if patients were catheterised less. It is important to address patients’ concerns about toileting when developing a strategy to avoid routine UC in surgery.

Abstract ID: 2815

Paradoxical increase in patient satisfaction scores during outbreaks of norovirus in a large teaching hospital

Carl Yates, Debbie Trigg, Tim Boswell, Natalie Vaughan
Nottingham University Hospitals

Introduction

Statement 9 of the NICE Quality Improvement Guide on the Prevention and Control of Hospital Acquired Infection recommends the collection of patient experiences during outbreaks of infection. Therefore we aimed to collect patient feedback data on the overall satisfaction of their inpatient stay in hospital during outbreaks of norovirus between April 2013 and March 2014.

Methods

Net promoter patient feedback data already collected on discharge was used to compare overall patient satisfaction in the 4 weeks following the start of each outbreak with data collected over a 4 week period during July 2013 when no wards or departments were affected by norovirus.

Results and Discussion

The results show that there were 23 outbreaks of norovirus during April 2013 to March 2014. Eighteen of these showed that patient satisfaction scores were greater during the outbreak than during July 2013 on the same ward when no outbreak was occurring.

Conclusion

The results show that patient satisfaction was greater during outbreaks in 78% of cases. This has generated local discussion in terms of whether a closed ward due to norovirus lends itself to a better nurse to patient ratio promoting more care time per patient and a greater focus on maintaining effective environmental standards thus increasing patient satisfaction. Although the net promoter question does not ask specific detail in terms of the patient’s perception of cleanliness and hygiene, it is suggested that a simpler, less detailed satisfaction survey may provide a more stable measure of overall standards within the organisation and increase interpretability of changes in patient satisfaction trends over time.

Abstract ID: 2823

Introducing initiatives, both conventional and unconventional, to improve the management of patients with diarrhoea associated illnesses and improve outcomes

Susan Roberts, Debbie Weston
East Kent Hospitals University NHS Foundation Trust

Improvement Issue and Context

The NHS Trust in question is the sixth largest acute Trust in England. During 2012/13, there were 444 patients with diarrhoea (and/or vomiting) who met the norovirus case definition, resulting in multiple bay/ward closures and disruption to services. There were also 40 cases of Clostridium difficile infection that year which resulted in the setting of an extremely challenging target of 29 cases for 2013/14. The high incidence of norovirus and challenging C. difficile target meant that there was an urgent need to develop new initiatives and “think outside the box”.

Methods and Measurement

VitalPAC IPC Manager software system was implemented in October 2013 providing the IP6C Specialist Nurses with a daily list of all patients reported as having diarrhoea (and/or vomiting). The IP6C Nursing Team have since implemented a system of timely follow up and assessment working collaboratively with ward staff.

Outcomes of Root Cause Analysis for C. difficile led to the implementation of the Diarrhoea Assessment Tool and various other novel initiatives, some unconventional, to improve the management of patients with diseases associated with diarrhoea.

The measurement of these interventions is described below.

Evidence of Improvement

Only one of the 3 hospital sites had any cases of norovirus (66 cases, compared to 200 cases in 2012/13) and there was an 87% reduction Trust wide. During this period there was a significant improvement in C. difficile from 28 in the first 2 quarters to 21 in the last 2 quarters of 2013/14.

Future Steps

New initiatives will continue to be developed in this area including the launch of our “Alternative Stool Chart” (based on chocolate, milkshake, and ice-cream analogies), to aid in the interpretation of the Bristol Stool Chart.

Abstract ID: 2829

Identification and characterization of staphylococcal small colonies variants (SCVs) from a Libyan hospital

Mohamed O Ahmed1, Asma Elramalli2
1Faculty of Veterinary MedicineUniversity of Tripoli, 2Tripoli Medical Centre

Introduction

We report the first laboratory examination and identification of small colony variants (SCVs) of staphylococcal species from a single-site hospital in Tripoli, Libya. Bacterial small colony variants are atypical organisms, showing unusual phenotypic and virulence characteristics. SCVs represent a challenge to the typical laboratory identification procedures and complicating clinical and antibiotic therapies.

Methods

A single-site collection of gram positive isolates (n=5) with unusual phenotypic and colonial characteristics was examined for SCV and wild type (WT) phenotypes based on cultural and biochemical characteristics and identified at the genera-species...
level by both API biochemical and automated identification systems. Also antimicrobial drug susceptibility profiling was carried out on both WT and the SCV colonies.

Results
Of the five isolates, Staphylococcus aureus (n=2), Staphylococcus hominis (n=2) and Staphylococcus epidermidis (n=1), were identified and characterized as typical SCVs with variable phenotypic and antibiotic resistance profiles.

Discussion
This report documents small colony variants (SCVs) of different staphylococcal species from a Libyan hospital. Health care authorities and practitioners should be alerted to the potential emergence of SCVs to aid in timely diagnosis and appropriate therapies.

Abstract ID: 2843
Development of an outbreak crib card to reduce omission error

Paul M. Southworth, Evonne T Curran
Health Protection Scotland

Improvement Issue and Context
Guidelines are available for outbreaks caused by common nosocomial pathogens such as Clostridium difficile. Infection prevention and control teams (IPCT) and national organisations also need to be prepared for outbreaks of rarer pathogens for which there may be no local experience nor national guidelines, e.g. nosocomial Bacillus spp. Should such outbreaks arise, the IPCT could be vulnerable to omission errors and possible delays in instigating appropriate investigations and control measures.

We describe the method used to produce the first Health Protection Scotland (HPS) Outbreak Crib Card with the aim to reduce the risk of omission errors and support optimal outbreak management.

Methods and Measurement
Medline and Cinahl databases were systematically searched for reports of healthcare-associated outbreaks and pseudo-outbreaks of Bacillus spp. Two products were produced: a summary evidence table and a crib card. The evidence table gives details of each outbreak found including the species implicated, the number of patients affected, fatalities, proposed route of transmission and any suspected environmental involvement. The crib card has 2 sides: 1) a short distillation of information on outbreaks commonly seen involving Bacillus spp and relevant factors; 2) advice for preventing, preparing for and controlling Bacillus spp outbreaks.

Evidence of Improvement
HPS now has a proof of concept Outbreak Crib Card for one rare type of outbreak. The Crib Card for B. cereus outbreaks has been presented to the Hospital Outbreak Advisory Group and discussed with infection control colleagues. It will be part of the HPS Outbreak Tool Kit.

Future Steps
The Crib Card will be tested during regular outbreak scenario training. Discussions with IPCTs as to how preparedness can be further increased by producing Crib Cards for other rare organisms that cause nosocomial outbreaks. Maintenance will be achieved through ongoing review of published outbreaks.

Abstract ID: 2856
An exercise aimed at integrating the use of N95 masks for protection against airborne infection and droplets.

Michiko Morimoto1, Hironobu Ikebara1, Tomohiro Azuma1, Masanori Ikeda1, Tsuneki Kusaba2, Atsushi Tago2, Takashi Yamamoto2, Takuma Shichiri2
1University of Hyogo, 2MORAIINE Corporation

Introduction
The purpose of this survey was to improve clinical practice for infection prevention among nursing students. We introduced the use of N95 masks and cough splash under the conditions of cough spray. They were able to deepen their knowledge and technical experience.

Methods
A survey was conducted with subjects for knowledge and technical competence scored on a five point scale. The sample consisted of 102 sophomore’s nursing students. The students were assessed according to how well they understood the use of the personal protective equipment for the purpose of infection control, and how well they could incorporate the infection prevention technology under conditions of cough spray. During the exercises nursing students wore PPE. To utilize N95 masks, the students made all the fitting tests. This study protocol was approved by the Ethics Committee of the University of Hyogo, in Japan.

Results
The responses of 57.8% of the students demonstrated the importance of wearing PPE for droplet infection prevention measures. The students also understood the importance and basis of wearing a mask as PPE by observing the scattered spray. The practice score was 4.1 points. A typical comment was “I was surprised by the range of spray.” A goal of more than 4.0 points average proving that they could utilize the N95 mask and the students scored more than 4.3 points.
Discussion
This training was highly effective in improving the skill of students with regard to the utilization of N95 masks and increasing their awareness of infection prevention. From their experiences, the nursing students understood the need to find a suitable mask size that suits them. Also, they were able to see the extent of spray with their own eyes.

Abstract ID: 2860

To investigate the separation rate and drug resistance of *Acinetobacter baumannii* in blood specimens of intensive care unit patients

Song Zhixiang, Wenyong Xue, Wei Chen
1Beijing Shijitan Hospital affiliated to Capital Medical University, Beijing, China

Introduction
To investigate the separation rate and antibiotic resistance of *A. baumannii* in blood specimens and to guide the rational usage of antibiotics.

Method
We retrospectively analysed the constituent ratio and antibiotic resistance of *A. baumannii* in the blood specimens of intensive care unit (ICU) patients during 2012 and 2013 at a large state hospital in Beijing.

Results
During the survey, the hospital detected 360 strains of bacteria from ICU patients’ blood specimens. The *A. baumannii* separation rate was 16.39% among all bacteria. They were all pan-drug resistant *A. baumannii* (PDR-AB) and showed high drug resistance and multi-drug resistance. With a resistance rate of more than 80% to 12 of the 15 antibiotics. The resistance rate to *Imipenem* was 100%. Antibiotic resistance rates of less than 50% were only *Cefoperazone/Sulbactam* with 5.36% and *Minocycline* with 34.78%.

Discussion
PDR-AB is one of the important pathogenic bacteria in bloodstream infections in ICUs. There are fewer antibiotics which can be selected for treating PDR-AB. A combination of *Cefoperazone/Sulbactam* and *Minocycline* are suggested for treating PDR-AB bloodstream infections. The ICU should properly control over-usage of *Imipenem* to reduce the development of PDR-AB. At the same time, the ICU should strengthen its environmental hygiene, the disinfection of hands and its sterile operations to avoid the nosocomial transmission of PDR-AB.

Abstract ID: 2868

Antiseptic agents in the treatment of chronic wounds with biofilm: an integrative review

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Introduction
This study aimed to examine the scientific evidence on the use of antiseptics on the healing of chronic wounds with biofilm in humans.

Methods
We conducted an integrative literature review considering publications from January 2000 to May 2014, using the databases COCHRANE, EMBASE, PUBMED, CINHAL.

Results
Twelve studies, who met the inclusion criteria, were included: two randomized clinical trials, one prospective cohort, one systematic review and eight narrative reviews. The randomized clinical trials included have low to moderate methodological quality, according to the Jadad Scale and tested different interventions. Both concluded in favour of the intervention (nanocrystalline silver and polihexadine), but have difficulty in affirming the action of the product tested in relation to biofilm. Both highlighted the number of narrative literature reviews that bring together some in vitro studies. The systematic review also examined in vitro studies to form its recommendations. A summary of the evidence provided by these reviews demonstrates that the biofilm is responsible for delayed healing and that there is need for improvement of techniques for its detection in wounds. The main antiseptics tested were: polihexadine associated with betaine; cadoxomer iodine; xylitol associated with lactofenin; nanocrystalline silver; honey. The evidence supports the use of the antiseptic agent, combined with debridement, to reduce and even inhibit bacterial load and hinder the accession of new biofilm in the wound bed. Also reinforcing the need for good practices associated with wound care to prevent biofilm formation.

Discussion
Although the studies included in this review indicate the use of debridement and antiseptic agent in the treatment of chronic wounds with biofilm, the evidence is weak and based on studies of low methodological quality. It is therefore, necessary to conduct further methodologically rigorous investigations, in humans, to assert which product is really effective in the treatment of wounds with biofilm.

Abstract ID: 2870

A cross-sectional survey of the use of temporary suspension of visiting during norovirus outbreaks in NHS Boards and the independent care home sector in Scotland

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Introduction
Noroviruses have been described as ‘the perfect human pathogens’, presenting significant challenges in care-settings as they are highly-communicable and have high survivability in the environment. Norovirus outbreaks are the commonest cause of healthcare service disruption due to ward closures. One means of reducing the incidence of norovirus is by reducing the flow of people ‘traffic’ in affected areas: this can be done by temporarily suspending visitors (TSV). Although widely publicised in the media, TSV is not currently routine policy in Scotland but is implemented in some care areas. This study aimed to describe current TSV practice in NHS Boards and the independent care home sector across Scotland.

Methods
An on-line cross-sectional survey of all NHS Boards’ Infection Prevention and Control Leads (n=21) and a convenience sample of independent sector care home managers (n=107) in Scotland was conducted.

Results
Analysis revealed distinct differences in the operation of TSV between NHS Boards and independent care homes and within NHS Boards. The majority of NHS Boards (n=13, 61.9%) do not have criteria to guide TSV decisions; conversely, the majority of care homes (n=8), 77.6%) do operate criteria for TSV. Respondents who had implemented a TSV in the last two years identified specific circumstances in which an exception would be made, including terminal illness, when a patient is confused and when the visitor has travelled a long distance or is insistent on visiting. The majority of both NHS (78.9%) and care home (78.8%) respondents believed TSV would be helpful in managing norovirus outbreaks.

Discussion
Our findings suggest that the current gap in policy guidance has resulted in a fragmented picture nationally, with inconsistent practice in evidence. This presentation will provide further detail of the analysis of the current nature of TSV practice across NHS Boards and the care home sector in Scotland.
Abstract ID: 2883

Programs for prevention and control of healthcare associated-infections: evaluation of its performance in hospitals of Parana State, Brazil

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Introduction
Programs for prevention and control of healthcare associated infections are important components of health systems for the evaluation of quality of health care facilities. However, the quality of these programs has been poorly investigated.

Objective
The purpose of this study was to determine and characterize the performance of these programs in hospitals in the State of Parana, Brazil. The hypothesis: a minimum 75% in compliance with Brazilian government requirements and international literature.

Method
A prospective cross-sectional study of process evaluation, applying a previously validated instrument consisting of 4 indicators related to the proper performance of the programs according to Brazilian government requirements and international literature. The indicators are: 1) Technical-Operational Structure (TOS); 2) Operational Guidelines (OGS); 3) Epidemiological Surveillance System (ESS); 4) Control and Prevention Proceedings (CPP). The study was conducted from 2013 to 2014 in 50 hospitals.

Results
Overall compliance achieved by these programs was 71.0%. The compliances of each indicator were: TOS-79.4%; ESS-76%; OGS-65.5%; CPP-63.2%. The overall performance was below that previously expected, because of the lower values obtained in OGS and CPP indicators.

Discussion
Programs have minimum suitability for its operation and to perform epidemiological surveillance. It is possible to consider that the appropriate process is hindered due to lack of quantitative and qualitative operational guidelines and actions to control and prevent these infections. Parana is considered one of the most developed states in Brazil, therefore, the results of this study are alarming and motivate the need to recognize and characterize these programs in other regions of the country. Finally, these indicators evaluation allowed further recognition of the modus operandi of associated infection control programs in health care. Moreover, further investigations need to be developed in order to recognize the impact of the conformity of these programs according to the occurrence of infections in healthcare institutions.

Abstract ID: 2900

Development of index for evaluating compliance on hand hygiene in dialysis unit in Japan

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Introduction
Although many measures for the improvement in hand hygiene (HH) and evaluation of compliance are performed, there is little extant evidence on dialysis units. A direct observation method has been recommended to evaluate HH compliance among health-care workers (HCWs), however, this method takes significant time and workload. Therefore, the purposes of this research were to develop a new index for evaluating HH compliance among HCWs in dialysis units and to examine its validity.

Methods
The formula of the developed index for HH compliance among HCWs in dialysis unit was as follows: Compliance rate = “total number of actual HH opportunities” / “the expected HH opportunities” × 100. To calculate the value of the denominator, we collected the data of its components, which are “disease severity classification of dialysis patients” and “indications for HH (care and treatment during dialysis)”, and set the numbers of them. To calculate the value of the numerator, the total amount of alcohol-based hand rub consumption was measured and divided by the amount of one-time usage. This study was approved by the ethical review committee.

Results
To examine its validity, the HH compliance rates by the developed index were compared with those by a direct observation method. The average compliance rate from May to September 2012 by the index was 25.5%, and the average HH compliance by the direct observation method at the same period was 33.4%. The result of regression analysis examining compliance rate by the index for each patient was reasonable as an index to predict the HH compliance rate by the direct observation method (R² = 0.549, S.E. = 0.061, p = 0.01).

Conclusion
Although it is necessary to examine the expected HH opportunities for different facilities, this developed index could be used as an alternative method for the direct observation to evaluate HH practice.

Abstract ID: 2904

Adopting an alcohol free hand rub into clinical practice

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Alder Hey Children’s NHS Foundation Trust

Improvement issue and context
Hand hygiene plays an essential role in infection prevention and control (IP&C). Alcohol hand rubs are popular. However problems with these rubs may include; skin stickiness/tackiness after use, the need to wash hands after several applications to remove emollient build-up from the skin, damage to paint/plastics/fabrics etc. where alcohol rubs splash/drip during use, limited virucidal efficacy, adverse skin reactions. IP&C at one NHS trust want to implement an alcohol-free hand rub throughout the new hospital which is currently undergoing construction and will be occupied in 2015. The improvement issue was to identify and evaluate a suitable alcohol-free hand rub for use within the new build.

Methods and measurement
In April/May 2013 IP&C identified a water-based, alcohol-free hand rub. Fifty ml tottles were issued to all staff in HDU and cardiology to determine user acceptance of the new product. IP&C monitored product usage and staff feedback over four weeks to determine product suitability for the new build when it opens.

Evidence of improvement
During the evaluation, use of the 50 ml tottles was high and staff had a clear preference for the water-based product over existing alcohol rubs. Feedback from staff was so positive that IP&C adopted the product trust wide, issuing all staff with 50ml tottles of the new hand sanitiser. Within the past 12 months staff have used in excess of 9,000 tottles, indicating excellent user acceptance. Staff were particularly impressed with how the product feels on their hands and the fact it left no tackiness/residue on their skin.

Future steps
Due to its popularity with staff, broad-spectrum antimicrobial efficacy and prolonged antimicrobial effect on the skin IP&C will be installing the water-based product as their hand sanitiser of choice once the new building is complete in 2015.
Abstract ID: 2907

Universal admission screening for antibiotic resistant organisms: assessing compliance for patients admitted to medicine units

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Providence Health Care, Canada

Introduction

Universal admission screening for antibiotic resistant organisms (ARO) was implemented on selected hospital units due to poor adherence with risk factor based targeted screening, and because we serve a high-risk patient population. The objective of this study was to evaluate compliance with universal admission screening for patients admitted from the emergency department to medicine units.

Methods

We conducted a cross-sectional chart review on four medicine units in November 2013. An Infection Control Practitioner (ICP) performed the review using the hospital’s patient care management system. Screening compliance was assessed by examining whether (1) the orders for specimen collection were entered and collected, (2) the location of the orders and the collection of the screening specimens (emergency or medicine units), and (3) the time from patient admission to the orders being entered and collected.

Results

Of the 102 patients on the four medicine units, 86 (84%) were admitted from the emergency department and were eligible for chart review. Of these, 66 (77%) patients had screening orders entered and 43 (65%) were from the emergency department. Among those with orders, 61 (92%) had specimens collected, the majority of which (47 (77%)) were collected on the medicine units. Almost all orders were placed (64 [97%]) and collected (56 [92%]) within 72 hours of patients being admitted to the medicine units.

Discussion

A high proportion of patients had ARO screening specimens ordered and collected within 72 hours of admission. Although there is still room for improvement to ensure patient orders are being entered on all patients, this review suggests that universal admission screening can be successfully implemented on selected units. Early detection of ARO colonization/infection among high-risk patients being admitted to hospital is essential to minimize health care associated ARO transmission.

Abstract ID: 2909

Implementing guidance on respiratory protective equipment (RPE)

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Health Protection Scotland

Improvement issue and context

The legislative requirements and product design features of Filtering Face Piece (FFP3) respirators present unique challenges in healthcare settings. This contributes to low healthcare worker compliance with national guidance on the use of RPE. Furthermore, a wide variety of different respirators are available across NHS Scotland. In this presentation we provide: an overview of the challenges in implementation of RPE; an assessment of the legislation on RPE fit-testing; and thoughts on developing a strategy to optimise RPE use by healthcare staff.

Methods and measurement

Health Protection Scotland (HPS) has engaged with the Health and Safety Executive (HSE), colleagues from NHS Boards and NHS Scotland’s National Procurement organisation to agree a national risk assessment for RPE use in healthcare settings. HPS has also examined: the variety of RPE products used across NHS Scotland; alternatives to tight-fitting FFP respirators (e.g. powered respirator hoods), including outcomes from a trial of disposable powered respirator hoods in NHS Forth Valley; the compatibility between NHS Board RPE stock and that of the national stockpile; and opportunities for RPE manufacturers/suppliers to undertake fit-testing across NHS Scotland.

Evidence of improvement

There is now an NHS Scotland agreed risk assessment for the use of RPE in healthcare settings. The number of types of FFP3 respirator in use has been reduced from 23 to six. It is hoped that this will simplify the procurement process and aid standardisation across NHS Scotland.

Future steps

An NHS Scotland-wide risk assessment on fit-testing is under consideration, and HPS is working with RPE manufacturers and product designers to develop a respirator that is better suited to the unique requirements of healthcare settings.

Abstract ID: 2910

Developing a national infection prevention and control manual for NHSScotland

Lisa Ritchie, Jackie McIntyre, Laura Macdonald
Health Protection Scotland

Improvement issue and context

In 2009, the Scottish Government tasked Health Protection Scotland (HPS) with developing a national infection prevention and control manual (NIP&CM) to reduce variation and optimise infection prevention and control (IP&C) practices throughout Scotland.

Methods and Measurement

Literature reviews generated IP&C recommendations based on best quality scientific evidence. Expert advisory groups with members from a range of disciplines representing every area in NHSScotland agreed pragmatic recommendations on issues with limited evidence.

These recommendations formed the basis of the NIP&CM, which was developed and finalised through an iterative process of consultations with expert advisory groups and wider stakeholder consultations.

The first chapter of the NIP&CM, Standard Infection Control Precautions (SICPs) was published in 2012 followed by Chapter 2, Transmission Based Precautions (TBPs), in 2014.

Evidence of Improvement

The NIP&CM became mandatory in 2012 under the instructions of the Chief Nursing Officer for Scotland, requesting adoption by all NHSScotland Boards. Feedback has been positive:

“There is now clear standardised information available for clinical staff throughout Scotland. Duplication of effort has been avoided, allowing time to be redirected and re-focused into other aspects of providing safe, effective and person centred care at the bedside.” [NHS Lanarkshire]

NHS Education for Scotland has developed IP&C educational resources for healthcare staff based on the content of the NIP&CM. The key recommendations in Chapter 1 of the NIP&CM are used by the Healthcare Environment Inspectorate as the basis for their safety and cleanliness inspections of NHSScotland hospitals.

Future Steps

Maintaining the NIP&CM to ensure it remains up-to-date and evidence-based. Consideration is being given to the addition of further chapters to supplement current content, and to the development of a NIP&CM webpage for Scotland. HPS are working with key stakeholders representing social care settings to ensure that the NIP&CM is applicable across all care settings.
Abstract ID: 2915

The introduction of blood culture packs to reduce MRSA bacteraemia and contamination rates

Angela Cobb
Queen Elizabeth Hospital Gateshead Health NHS Foundation Trust

Introduction
Previously, within the organisation, if a patient has suspected sepsis and blood cultures were required, the necessary equipment for the procedure was collected separately. In 2008/2009 the blood culture contamination rate was above the national expectation at 5% and the health care acquired MRSA bacteraemia rate was ten.

Methods and measurement
A system was developed to ensure all necessary equipment for blood cultures was centrally located with the aim of promoting Aseptic Non Touch Technique (ANTT) and reducing the bacteraemia and contamination rate. Within one year the contamination rate had reduced to the national expectation of <3%.

The Infection Prevention and Control Team (IPCT) worked collaboratively with other Trust staff to ensure correct equipment was available in all clinical areas. An outcome following discussion was that the equipment should be produced in a single pack. Procurement sourced an appropriate sized tray for all of the products to be stored in. However, it was identified that all of the products were from different manufacturers therefore no single company could produce a single pack. To overcome this difficulty, CSSD was approached and asked if they could manufacture a blood culture pack with all of the sourced equipment. This was agreed, trialled and implemented with educational support for the clinical teams from the PDT.

IPCT also supported this focused work with the implementation of an IPCN investigating blood culture contamination results. Difficulty in tracing the individual practitioner was recognised and after discussion with clinicians, an identification label was devised and added to the pack which clearly identifies the printed name of the person taking the blood cultures and if the ANTT was compromised.

Evidence of improvement
The development of the blood culture packs and the named identification labels has assisted in the sustained reduction of the organisations blood culture contamination and MRSA bacteraemia rate.

Abstract ID: 2922

Aseptic Non-Touch Technique in nail surgery and wound care in podiatry

Mohammed Tamim
Berkshire Healthcare Foundation Trust

Introduction and Rationale
Nail surgery procedures in podiatry pose a higher risk of wound infection than non-invasive procedures. Poor asepsis can lead to the risk of cross contamination of microorganisms from the healthcare workers’ hands and/or the equipment to susceptible patient sites, which can result in life threatening infections. The primary objective of the project was to review aseptic non-touch technique (ANTT) practice and adapt the ANTT Standard Operating Procedure (SOP) against best practice guidelines.

Methods & Measurement
The visits have been completed in 7 podiatry clinics in the BHTF East since May 2013. Individual members of staff were also assessed on their hand hygiene compliance based on WHO 5 Moments of Hand hygiene at the point of care.

Evidence of Improvement
We report the score compliance in three aspects of infection control namely five moments for hand hygiene, use of PPE and safe management of sharps during invasive procedure.

Future Steps
It is recommended that the instrument pack should be placed on sterile drape on the table and sterile instruments spread out carefully to ensure they are not touching each other. Staff should pick up the sterile gauze with a nominated hand, dip into saline and pass it to the other hand or use forceps. Staff must ensure that all packs and instruments are available at the beginning of the procedure. Sterile paper towel should be used prior to nail surgery. Staff should avoid over use or unnecessary use of sterile gloves. Apron should be worn prior to hand washing. The challenge remains to embed standard process in all areas to ensure all staff members perform the appropriate ANTT procedure in the Podiatry clinic.

Abstract ID: 2920

Implementation of glycopeptide resistant enterococci screening - results for action?

Vickie Longstaff, Gema Martinez-Garacia, Monique Laberinto
Homerton University NHS Foundation Trust

Introduction
There were four cases of glycopeptide resistant enterococci (GRE) isolated from patients on the intensive care unit (ICU). Previously GRE cases were rarely seen. Three of the isolates were sent for pulsed-field gel electrophoresis (PFGE) typing. Two represented a single strain, not previously reported from the hospital. Following implementation of a number of actions from the reviews of the environment and practices the number of cases reduced.

Discussion
Prior to the first cluster of cases the number of GRE cases on the ICU was low. The significance of the typing results from screening swabs was questioned and it was possible that there could be isolates with similar patterns among epidemiologically unrelated isolates. The implementation of a complete review of practices and decontamination processes reduced the number of cases.

Abstract ID: 2936

Developing an understanding of the culture of visiting time to identify opportunities for reducing the risk of healthcare-associated infection in the older people’s ward of an acute hospital

Denise Richards
Poole Hospital NHS Foundation Trust

Introduction
Current developments in infection prevention and control (IPC), whilst acknowledging wider holistic factors, remain for the most part applied to healthcare
is imperative to minimize exposures and health-care associated transmission.

Methods
A qualitative, ethnographic approach utilising non-participant observation and documentary review was used to collect data over a four month period. Data was analysed through domain and taxonomic analysis to identify themes relevant to IPC.

Results and Discussion
Visiting time was found to comprise a complex performance of roles by individuals and groups who whilst sharing the same focus i.e. the best interest of the patient, demonstrate different and competing needs. The central theme identified was a form of negotiated order, which whilst serving the goals of individuals was not found to always support best practice in IPC. Opportunities to improve IPC can be achieved through greater understanding of visitor and patient needs with enhanced interaction by healthcare professionals to negotiate in favour of IPC.

Abstract ID: 2937
Implementation of a tuberculosis airborne line list as a tool to improve infection control interventions
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Introduction
Tuberculosis (TB) can be a diagnostic challenge and failure to consider TB on the differential diagnosis can result in exposures and nosocomial transmission. The Canadian TB Standards recommend that airborne precautions be implemented for patients suspected of active pulmonary TB. We developed and evaluated a TB airborne line list (TALL) as a tool for optimizing infection control interventions for patients, including those not placed on airborne precautions within 4 hours of hospital admission.

Methods
TALL is a consistent and systematic approach to identify and follow patients with suspected TB based on acid fast bacilli (AFB) orders from our patient care management system. At two acute care facilities in Vancouver, Canada, from September 2012 - May 2014, the Infection Prevention and Control team reviewed all patients using TALL that were not placed on airborne precautions within 4 hours of admission. Documented reasons for non-adherence with airborne precautions, subsequent interventions and laboratory-confirmed TB cases were reviewed.

Results
Over the study period, 748 patients were identified by TALL and 592 required airborne precautions. Of these, 156 (26.3%) were not placed on airborne precautions within 4 hours. Reasons for non-adherence included: low clinical suspicion (70.5%) and AFBs ordered but airborne precautions not actively implemented (26.3%). Infection control interventions included: consulting with the Medical Nursing care teams (89.7%), requesting airborne precautions (56.4%) and recommending additional testing (26.9%). Six (3.8%) of these patients were ultimately found to be TB positive.

Discussion
TALL has provided a consistent and systematic approach to identify patients that are not placed on appropriate airborne precautions for suspected TB, to improve communication and awareness with the patient care team, and to recommend additional testing and isolation precautions, as required. Early consideration of TB is imperative to minimize exposures and health-care associated transmission.

Abstract ID: 2947
Understanding factors influencing paediatric nurses compliance with standard precautions: a qualitative study
Murad Sawalha
The University of Hull

Introduction
Healthcare associated infections (HCAIs) are problematic in hospital environments worldwide, resulting in increased patient morbidity and mortality. Health-care professionals play a vital role in the prevention and control of HCAIs by adhering to evidenced based standard precautions guidelines (SPGs). Non-compliance with SPGs can negatively impact on paediatric patients by increasing their hospital stay, exposing them to the complications of infections and increasing their treatment costs.

Aim
This study was designed to identify how the experience of nursing children affects nurses’ decisions regarding compliance with SPGs. It clarifies paediatric nurses’ understanding of factors affecting compliance and identifies their perceptions of how to increase compliance.

Methods
This study used a qualitative pragmatic design based on both phenomenology and grounded theory. It was conducted in five Jordanian hospitals and employed purposive sampling of 31 qualified paediatric nurses working in different paediatric areas.

Results
Barriers and facilitators to compliance with standard precautions were identified by the participants, with some backed up from peer reviewed literature. The main factors acting as barriers included: workload and poor staffing; negligence; conflicting policies; lack of equipment; knowledge deficit; emergency situations and poor management. The facilitators included: motivation; protection and safety; religious beliefs; cooperation; monitoring and reminder systems. Practitioners highlighted that nursing children impacted both positively and negatively on infection control practice.

Discussion and Conclusion
In general nurses thought that compliance was suboptimal in paediatric departments, but better than in other departments. HCAIs and suboptimal compliance with precautions was viewed as a global problem. Hospital administrators and policy makers should develop effective strategies and policies to improve infection prevention and control programs to find solutions and support compliance facilitators.

Abstract ID: 2949
Characterization of services to prevent and control healthcare-associated infection in Brazil
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Introduction
In Brazil, since 1987, it is mandatory that hospitals must have services to prevent and control healthcare-associated infections (SPCHAI). However, regional and economic differences often define the gap between social reality and law.

Objective
To characterize the SPCHAI in hospitals from Paraná state (Brazil) and to recognize the difficulties in carrying out its activities.
Introduction
Mater Dei Hospital, Malta

Abstract ID: 2951
Looking for the needle in the haystack: a cluster of pacemaker surgical site infections
Deborah Xuereb, Vincent Gatt, Michael Borg
Mater Dei Hospital, Malta

Introduction
Following reports by cardiologists suggesting an increase in permanent pacemaker (PM) surgical site infections (SSIs) in our Cardiac Catheterization Suite (CCS) in June 2013, retrospective review identified nine infections over 4 months. Four cases required explantation.

Methods
We collected epidemiological data from patient and CCS records. We process mapped the patients’ journey through observation of practice within the CCS and outpatient clinic and discussions with the teams. Several practice shortcomings were identified, changed and the changes documented in a revised CCS infection control policy.

Results
Lack of information prevented historical PM SSI comparisons. All cases presented within 2 months of procedure in new device implantations or box changes. Five had positive cultures from the wound or aspirate from the surgical site. All microorganisms cultured were different and all cases were operated on by different personnel. No single point source or cause could be identified but no further SSIs were reported in the twelve months following practice changes. Further cases were reported in the twelve months following the interventions. SSIs in PM are rare but serious. Management is traumatic for patients and costly; removal of implanted material requires transfer to a specialist centre in Italy, costing circa €100,000. CCS practices are crucial in preventing PM SSIs and should be audited routinely. Surveillance of PM SSI could result in early identification of clusters.

Discussion
Paraná, one of the most developed Brazilian states, has not yet established SPCHAI in all hospitals. After 27 years of implementation of specific legislation and regulation. All SPCHAI heed the mandatory requirement for nurses and other healthcare personnel. Nurses devoted more work hours to SPCHAI. In addition, minor difficulties related to structure, material resources and support from managers show that the main problems for improving the SPCHAI are more related to human resources than to regional and socio-economic differences.

Abstract ID: 2961
Compliance with hand hygiene for circulating health-care professionals in an operating room setting: an observational study in Japan
Hiromi Murata
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Background
Compliance with hand hygiene (HH) of circulating health-care professionals (CHCPs) in operating rooms (OR) has not been adequately measured in Japan. Therefore, the purpose of this study was to measure HH compliance for CHCPs in OR using the World Health Organization’s (WHO) 5 moments for HH.

Methods
Data collection was conducted at an OR of one general hospital in Japan. A primary researcher performed direct observations of CHCPs who were engaged
in total hip arthroplasty (THA) and total knee arthroplasty (TKA) procedures from April to September, 2012. HH opportunities were observed using the WHO’s 5 moments. HH compliance rate was calculated using the following formula: The total number of HH opportunities that CHSPs actually did during the above surgeries / the total number of HH opportunities that CHSPs were required during the above surgeries X 100 (%). The protocol of this study was approved by the ethical review committee of International University of Health and Welfare.

Results

During the study period, 27 THA and TKA procedures were observed. The total observation time was 95.9 hours and the number of the required HH opportunities was 3,916. The number of the actual HH opportunities was 1,187. The mean HH compliance rate was 30.3%. The compliance rate of nurses was statistically significantly higher than other CHCPs (p<0.05). For the WHO’s 5 moments, the compliance rate after contact with body fluids or excretions was the highest, 42.7%. On the other hand, the rate after patient contact was the lowest, 21.7%.

Conclusions

Although the surgical procedures were limited to THA and TKA, this study is the first report of the compliance rate of CHCPs in OR by the direct observation using WHO’s 5 moments. The number of HH opportunities which CHCPs were required seems to be higher than for HCWs of wards, and the compliance rate of CHCPs was relatively low.

Abstract ID: 2962

Improving isolation in critical care using the Bioquell Pod

David Tucker
Guy’s and St Thomas’ NHS Foundation Trust

Improvement Issue and Context

Intensive Care Units (ICUs) frequently care for patients requiring single rooms, including an increasing number who are colonized with multidrug-resistant pathogens; however, single rooms are in short supply in many NHS ICUs. The Bioquell Pod is a semi-permanent structure that is used to provide additional single-occupancy pods in multi-occupancy areas.

Methods and Measurement

Due to a relative lack of side rooms (less than 10% of total critical care beds), two Pods were installed in the ICU. Usage of the Pods was monitored and evaluated through discussions with patients, relatives and staff.

Evidence of Improvement

Installation of the Pods was achieved quickly and with minimal disruption. The Pods enabled isolation of high-risk patients (including CPE carriers), who would otherwise have been nursed on the open bay. Patients and relatives preferred the improvement in privacy and dignity, and especially noise and light reduction at night. In terms of drawbacks, staff noted: increased staffing pressures, isolation from colleagues and tiredness, reduced ability to respond to emergencies, heat gain, and delays in discharging patients to wards (isolation to isolation). Staff noted the following benefits: improved infection prevention and control capacity, increased footprint of the bed spaces, improved physical definition of the isolation cubicles, and the ability to terminally decontaminate using hydrogen peroxide vapour (HPV).

Future Steps

The Pods on the ICU are viewed as a positive addition to existing facilities, and have been generally well received by staff and patients. They have improved the options for housing patients requiring isolation precautions and potentially allow admission of patients with infection risk more rapidly from A&E. The Trust is currently evaluating the installation of pods in other areas of the critical care service and in other services throughout the Trust.

Abstract ID: 2966

Does converting a ward to single rooms reduce rates of infection? A systematic review

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Introduction

Single rooms provide physical segregation of patients, which many consider to be important in reducing the transmission of key hospital pathogens such as MRSA, Clostridium difficile and CPE. However, the majority of bed spaces in the NHS are in multi-occupancy bays. The importance of single rooms in reducing transmission can be inferred by evaluating the impact of converting multi-occupancy bays to single rooms.

Methods

PubMed was searched using the following term without date or language restrictions: “conversion room infection”. In addition, bibliographies of articles identified by the database search were hand-searched. Studies were eligible for inclusion if they reported the impact of converting a multi-occupancy ward into a single occupancy ward including some measure of infection or colonization rate.
Results
A total of seven articles met the inclusion criteria. All studies were performed in the critical care setting. Study lengths ranged from 11 months to 20 years. Two studies included the use of a control ward, whereas five studies evaluated rates of infection before and after the conversion. Infection outcomes varied, including infection / colonization with individual or all pathogens. Six of the seven studies reported that converting a multi-occupancy ward into single rooms reduced infection / colonization rates. The one study that did not identify reduced infection lacked a control unit, and reported low rates of hand hygiene compliance before and after the intervention (18% vs. 24%).

Discussion
It is not clear whether reduced infection associated with conversion to single rooms is due to improved physical segregation of patients, or other factors, such as improved hand hygiene compliance. Furthermore, single rooms can have drawbacks, such as negative patient experiences due to isolation or harm due to reduced observation. Nonetheless, conversion to single rooms is associated with reduced rates of colonization or infection with hospital pathogens.

Declaration of Conflict of Interest
Jon Otter is employed part-time by Bioquell.

Abstract ID: 2970

Carbapenemase producing Enterobacteriaceae: emergence and management in the acute setting

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Background
The first CPE was identified within our Trust during 2009, and the numbers increased considerably during 2010/2011. In order to manage the situation and limit spread, the Trust adopted a proactive response employing a number of management strategies in conjunction with Public Health England.

Aim
To describe the management and control strategies implemented.

Method
The identification and subsequent rise in the number of patients with CPE was raised at Board level and a control strategy put into place to manage the incidence of CPE across the whole organisation. Here we describe the management strategies employed and describe our screening programme.

Discussion
The number of patients in the Trust who are colonised with CPE remains above the national average, but shows no sign of worsening. CPE persists within the Trust despite careful management and interventions since its emergence, due in part to the number of colonised patients who are re-admitted for further care. Enhanced surveillance and proactive management has proved essential in limiting the spread of CPE.

Abstract ID: 2973

Improving isolation capacity in an acute foundation trust using the Bioquell Pod

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City Hospitals Sunderland

Improvement Issue and Context
Our Infection Control Ward has a mixture of single rooms and bays. Patients with the same infectious disease are cohorted together in the bays; this can result in underutilisation of the ward, as empty beds in mixed bays cannot be used to accommodate patients with different infections. The Bioquell Pod is a semi-permanent structure providing additional single room capacity within bays.

Methods and Measurement
Following extensive consultation with key stakeholders, two Pods were installed into bays on the ward to increase the number of single occupancy bed spaces available. In order to gather feedback, patients; relatives and staff were issued a questionnaire to complete.

Evidence of Improvement
The Pods were installed with minimal disruption, with the bay closed for five days during installation. All other beds on the ward remained open. Six patients and eight staff members completed questionnaires. Patients and staff were satisfied with the Pod in >70% of their responses, and <10% indicated dissatisfaction. Patients commented that the Pods were warm and initially dingy, but that they were spacious and private. Staff commented that the Pods were warm, however increased the capacity for isolation, were high quality appearance, offered increased privacy and dignity and provide more flexibility especially at times of bed pressure.

Future Steps
The Pods have provided a high standard of patient care and greater flexibility in caring for a variety of patients requiring isolation. We believe they have reduced the risk of the spread of infection by increasing side room capacity and negating the need to nurse patients in bays. We hope to extend the evaluation of the Pods for a further six months to gather additional quantitative evidence.

Abstract ID: 2974

Keeping an eye on new ophthalmic procedures

Catherine Cook, Peter Addison, Carlos Pavesio
Moorfields Eye Hospital NHS Foundation Trust

Introduction
In February 2013 the infection control nurses identified from surveillance systems three cases of endophthalmitis following biodegradable dexamethasone implant injections. This was a relatively new procedure approved by NICE in 2011 but published with very low rates of infection. The infection control team had developed a benchmark for intravitreal injections but this procedure was considered to be more complex and have the potential for more severe outcomes. The clinical lead and infection control team agreed to establish the trust rate of infection, centralise data, monitoring and institute control measures for practice.

Methods
The cases of endophthalmitis were retrieved from the infection control surveillance system. The numbers of procedures were obtained from all sites via pharmacy records and clinician records. The clinical lead developed a central data system with pharmacy and implemented a competency process for all new clinicians administering the implant.

Results
Three cases of endophthalmitis were identified from a total of 446 procedures. This resulted in a trust rate of infection of 1.149 or (0.67%). The data showed that most patients had received one implant, but around a quarter had received multiple doses. The patient cases developed endophthalmitis at 1st, 2nd and 3rd dose respectively. Two of the three surgeons involved in patient cases had low levels of experience, however, following competence training no further cases have emerged.

Discussion
The trust rate of 1.149 was considered comparable to the HURON study that reported one possible case of endophthalmitis in 153 procedures. However, it was difficult to benchmark with a similar organisation as the number of procedures excelled other ophthalmic units. There was also limited research into the effect of multiple doses.
Abstract ID: 2979

Validation of the Sanicare compliance program enabling hospitals to comply with epic 3 hospital environmental hygiene requirements (SPI-5)

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Improvement and Context
Sanicare was implemented in a test ward at Royal Liverpool Hospital to determine if making the products available at point of use, ensuring staff receive appropriate training, and the ongoing measurement of the training and ATP levels, would improve the hospital’s compliance to epic3 (SPI-5).

Method and Measurement
A test and control ward was used. The program was implemented in the test ward, with no intervention in the control ward. A Qualitative (Training recollection), and Quantitative (ATP on 30 of the same devices) base-line audit was undertaken in both the control and test wards. This was followed by 3 further audits, at 4 week intervals (same days and time of the week).

Evidence of improvement
1) Qualitative Audit
In the control ward the questions were not answered correctly. The test ward results showed an improvement in the questions being answered correctly.

2) Visible clean Audit (epic SPI)
Surfaces in both the control and test ward achieved 100% compliance during the 12 week test period.

3) Quantitative Audit - Utilising ATP
The evidence from the study showed over the 12 week period that the test ward, was able to reduce bioburden from visibly clean surfaces by 72%, whilst the control ward had an increase of 27% from its baseline audit. The improved understanding, technique and frequency of cleaning resulted in improved compliance leading to better cleaned devices.

Future steps
To implement the Sanicare compliance program across the whole Trust.

Declaration of Conflict of Interest
PDI Ltd who supply the Sanicare compliance package provided this package to the Royal Liverpool & Broadgreen Hospital Liverpool. Linda Knight and Glen Harrison are employees of PDI Ltd.

References and definitions
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Abstract ID: 2980

Diagnostic dilemmas and infection control implications for cystic fibrosis

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Introduction
Pulmonary decline, exacerbated by bacterial infection, classically resulted in the early death of cystic fibrosis (CF) sufferers. Due in part to the introduction of rigorous infection control measures and aggressive antibiotic treatment regimes, survival rates have dramatically improved. Pseudomonas aeruginosa and members of the Burkholderia cepacia complex (Bcc) have the greatest impact on lung health so rapid, accurate identification methods are fundamental to the success of treatment and infection control strategies.

Methods
Precise identification of bacterial pathogens from patients attending a paediatric CF Centre relies on in-house molecular methodology and referral of isolates to a Reference Laboratory. These results were compared to those generated by the BioMerieux Maldi-TOF available on-site and the Bruker Maldi-TOF available in other Scottish Laboratories.

Results
Five isolates categorised as Pseudomonas aeruginosa on the BioMerieux system were identified by in-house 16s ribosomal DNA sequencing or Reference Laboratory testing as P. maltophilia. On retesting on the Bruker Maldi-TOF all 5 strains were identified as P. maltophilia. Ninety four PCR-confirmed Bcc strains were tested in parallel and both Maldi-TOF machines categorised them within the cepacia complex. At Genomovar level, B. multivorans and B. vietnamiensis gave concordant results on the 2 systems. All of 28 B. cepacia identified on the BioMerieux Maldi-TOF were B. cepacia according to Bruker.

Discussion
Maldi-TOF technology offers the prospect of rapid generation of clinically valuable information to enhance treatment and infection control in the CF setting. Misidentification of Pseudomonas is unacceptable as incorrect segregation and antibiotic management of patients would ensue. Additional concerns apply to inaccurate characterisation of B. cepacia, which is understood to be the most aggressive Bcc strain and currently precludes lung transplantation. Refinement of Maldi-TOF databases to overcome the anomalies identified in this study is essential before this technology can replace current DNA based identification methods.

Evidence of Improvement
Success of the campaign and compliance was measured through direct observation of hand hygiene practice. Overall compliance increased from 66% to 78%.
Abstract ID: 2985

Prevalence of hypothermia in surgical patients

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University Hospital Coventry and Warwickshire

Introduction

Monthly point prevalence audit of Surgical Site Infection (SSI) has been undertaken at University Hospital Coventry and Warwickshire (UHCW) NHS trust including compliance with NICE (2008) SSI guidelines since January 2013. This data collection has shown a number of themes where UHCW were not compliant with NICE recommendations, the most significant being patient hypothermia at pre, peri and post operative stages. The data collected in the point prevalence study has limitations and therefore a temperature specific audit was required to gain a more in depth analysis of hypothermia during pre, peri and post operative stages.

Methods

Audit was undertaken over a two-week period in September 2013. One hundred and fifty four patient records were collected reflecting approximately 17% of the patients undergoing surgery. Sample size on commencement of the audit was not limited. Previous data collections of similar audits have been varied in response rate and audit completion has been unpredictable. The data was collected on the day of surgery by recovery staff whilst the patient was awaiting theatre to ward transfer. Data collected included: ward temperature; holding bay temperature; peri-operative temperature; and post operative temperature. Further information was obtained via patient identification number. The term “Cold” was applied to temperatures of 35.9°C and below.

Results

Results showed those requesting surgical specialities on day of admission had higher prevalence of hypothermia. Those attending theatre cold had a 45% chance of remaining so, of the 97 patients pre-operatively within normothermia range, 97% remained warm post operatively, providing strong evidence towards pre-operative warming.

Discussion

From this audit recommendations have been highlighted including; staff and patient clarification of hypothermia/normothermia and its links to SSI outcomes, involvement of different groups in data collection to ensure meaningfulness of data to allow behavioural change and improvement of warming equipment availability.

Abstract ID: 2990

How long do SARS and MERS coronaviruses, and influenza survive on dry surfaces? A systematic review

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Introduction

A number of important viruses with pandemic potential have emerged in recent years, including H1N1 and H5N1 influenza, and SARS / MERS coronaviruses.

Methods

PubMed was searched using the following terms with no date or language restrictions: [coronavirus or influenza] AND survival surface OR fomite transmission OR surface contamination OR disinfection transmission. Articles were included if they evaluated survival of influenza of SARS / MERS and their surrogates on dry surfaces in laboratory studies, or in field settings.

Results

Thirty one articles met the inclusion criteria. SARS, MERS and influenza have the capacity to survive on environmental surfaces for extended periods, sometimes measured in months. Important factors that influence the survival of these viruses on surfaces include: strain variation, titre, substrate, suspending medium, mode of deposition, temperature and relative humidity, and the method used to determine the viability of the virus. All these viruses are able to survive in an aerosol for a considerable length of time. Environmental sampling has identified contamination of inanimate surfaces is uncertain compared with other routes. The contamination of inanimate surfaces is uncertain compared with other routes. The infection prevention and control implications of these findings include the need to combine with hand hygiene and enhanced surface cleaning and disinfection.

Discussion

Influenza, SARS and by extension MERS are shed into the environment, can survive for extended periods on surfaces and can be transferred from surfaces to hands. Contaminated hands can then initiate self-inoculation through contact with the nose, eyes or mouth. However, the importance of contact transmission involving contamination of inanimate surfaces is uncertain compared with other routes. The infection prevention and control implications of these findings include the need to wear appropriate PPE to account for contact, droplet and airborne transmission routes, including gloves, gowns, an N95 / FFP3 mask and eye shield / goggles, combined with hand hygiene and enhanced surface cleaning and disinfection.

Conflicts of interest

Jon Otter is employed part-time by Bioquell.
Infection prevention in community settings

Abstract ID: 2807

Current knowledge, attitude and behaviour of hand and food hygiene in a community of a developed country: a cross-sectional study

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Background
Although there is great accessibility and availability to clean water, sanitation and hygiene promotion in developed countries, diarrhoeal incidence has moderately increased over the past years. The aim of this study was to determine the current knowledge, attitude and behaviour towards hand and food hygiene in a developed country so as to provide a better understanding behind the increasing diarrhoeal incidence.

Methods
A cross-sectional study was conducted in a residential area in the west of Singapore from June to July 2013. A total of 1,156 household units were randomly sampled and invited to participate in an interviewer assisted survey using standardized questionnaires. Analyses were performed using descriptive statistics, Fisher’s Exact Test and multivariate logistic regression.

Results
A total of 240 units (20.8%) responded and consented to the survey invitation. About 77% of the questions on knowledge and attitude, and about 31% of the questions on behaviour had over 80% choosing the ideal response. Being single [adjusted odds ratio (AOR)=2.29, 95%CI=1.16-4.48], having flu in the past six month period (AOR=3.24, 95%CI=1.74-6.06), preferred self-medication (AOR=2.07, 95%CI=1.06-4.12) were risk factors of diarrhoea. Washing hands with water before attending to children or sick persons (AOR=0.30, 95%CI=0.11-0.82), washing hands with water (AOR=0.16, 95%CI=0.05-0.45) and with water and soap (AOR=0.29, 95%CI=0.12-0.72) after attending to children or sick persons, and hand washing between 30 seconds to a minute (AOR=0.44, 95%CI=0.20-0.90) were protective factors against diarrhoea. Interventions such as a self-reporting online portal, early emphasis since young age, provision of alcohol-based disinfectant on public transport system, and annual hygiene campaign were well-accepted and may reduce diarrhoea incidence.

Discussion
The good knowledge and attitude of the participants did not completely influence their compliance and motivation to perform good hygiene practices. This lack of compliance may attribute to the increasing diarrhoeal incidence in a developed country.

Abstract ID: 2810

Catheter designs, techniques and strategies for intermittent catheterisation – What is the evidence for preventing symptomatic UTI and improving user acceptability? A Cochrane systematic review

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Introduction
The most frequent complication of intermittent catheterisation (IC) is urinary tract infection (UTI), but user acceptability and ease of use are also important. It is unclear which catheter designs, techniques and strategies affect the incidence of UTI, are acceptable to users and are cost effective.

Objectives
To compare in relation to UTI, other complications and user acceptability: single-use (sterile) versus multiple use (clean) catheters, one catheter design versus another (e.g. hydrophilic-coated versus uncoated), aseptic versus clean catheterisation technique.

Methods
We searched the Cochrane Incontinence Group Specialised Trials Register (updated Sept 2013), reference lists of relevant articles, conference proceedings and contacted other investigators for unpublished data. Inclusion criteria were randomised controlled trials or randomised crossover trials comparing at least two different catheter designs, catheterisation techniques or strategies. Two reviewers assessed the methodological quality of trials and abstracted data as per standard Cochrane methods.

Results
Thirty one studies met the inclusion criteria. A total of 1737 participants were enrolled and 1388 (80%) completed. Sixty per cent of participants were male. There were no significant differences between single-use (sterile) catheters versus multiple use (clean) catheters, aseptic catheterisation technique versus clean technique, or one catheter design versus another. Most studies were small and underpowered. Attrition was a problem which may have led to bias. There was considerable variation in length of follow-up and definitions of UTI. No studies addressed cost effectiveness. Where there were data, confidence intervals were wide and hence clinically important differences in UTI and other outcomes could neither be identified nor reliably ruled out.

Discussion
Despite 31 randomised trials on intermittent catheterisation, there is still no convincing evidence that UTI, other complications and user acceptability are affected by the use of single-use catheters, by catheters with specialised coatings or by the use of sterile technique.

Declaration of Conflict of Interest
Katherine Moore was a co-investigator on a trial sponsored by Coloplast (Cardenas 2011) and received products from Coloplast for another trial (Moore 2013). Mandy Fader has received intermittent catheter products for research purposes from Astra Tech AB.

Abstract ID: 2842

Preventing infection workbook - an innovative way forward for delivering IPC education

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Improvement issue and context
We provide an Infection Prevention and Control (IPC) service to 156 GP Surgeries across North Yorkshire. Since April 2013, GP Practices had to register with the Care Quality Commission and achieve compliance with the Health and Social Care Act 2008 which states that all staff receive IPC education.

Methods and measurement
Due to the wide geographical area and number of GP Practices, delivering IPC education face-to-face would be an impractical option as well as e-learning, as many staff encounter difficulties with computer access. Therefore, as we had previously produced a highly acclaimed Workbook for Health and Social Care staff...
we concluded that production of a Workbook for all staff in GP Practice would be the best approach.

The innovative A5, 68 page Preventing Infection Workbook and Guidance for General Practice is aimed at not only frontline clinical staff but all groups including receptionists. The Workbook is designed so each member of staff receives their own copy and can work through it at their own pace. It provides latest national guidance and evidence-based information on topics such as Hand Hygiene, Standard Precautions, MRSA, Clostridium difficile, MRGNB and norovirus. Each topic includes ‘It’s a fact’ and ‘test your knowledge’ sections. When 100% competency has been achieved, managers sign the ‘Certificate of Completion’ at the end of the Workbook, providing evidence for CQC compliance. The Workbook is kept by the member of staff as part of their portfolio of evidence of learning and can be used as a reference guide for day-to-day working.

Evidence of improvement

The Workbook has been extremely well received by all our GP Practices and is viewed as best practice by local CQC inspectors. We aim to make the Workbook available to GP Practices nationally to purchase, with the aim of improving IPC standards and helping GP Practices achieve CQC compliance.

Declaration of Conflict of Interest

The Preventing Infection Workbooks for General Practice were provided free of charge to all our GP Practices. They are now available to purchase nationally at a cost to cover production and printing.

Abstract ID: 2864

Issues concerning the uptake of the seasonal influenza vaccine by nurses working in the long-term older person setting in Ireland

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Introduction

The experience of nurses who work in the long-term care setting for older people regarding the seasonal influenza vaccine is often overlooked, with a paucity of published qualitative studies in the literature. Systematic reviews of the literature acknowledge this deficiency and make reference for the need to explore the specific views of nurses regarding influenza vaccination. Hence, the importance of this study.

Methods

Using a broad qualitative research approach, data was collected through audio taped semi-structured individual interviews. The data was thematically analysed using guidelines developed by Braun and Clarke (2006).

Results


Conclusions

From this study it emerged that nurses’ views of the seasonal influenza vaccine may be influenced by multiple complex factors such as media, family, alternative medicine, peers and trusted role models. Unlike some of the findings alluded to in published quantitative data, nurse participants in this study demonstrated some general knowledge of the seasonal influenza vaccine and a desire to protect their patients.

However, participants were unaware of the possibility of asymptomatic carriage by themselves and that the vaccine is inactivated and that collective vaccination is required to elicit protection for older persons in the residential long term care setting. Findings further suggest that the position of nurses within the organization may acknowledge this deficiency and make reference for the need to explore the specific views of nurses regarding influenza vaccination. Hence, the importance of this study.

A recommendation from this study is that health care policy makers should collaborate with nurses to devise health strategies that incorporate the diverse empirical, aesthetic, and moral ways of knowing that are unique to nurses (Carper, 1978) to reach a concordant holistic policy that considers the well being and concerns of nurses as well as patients.

Abstract ID: 2891

Switching from saline solution to an antimicrobial solution for skin cleansing before urinary catheterization

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Improvement Issue and Context

Urinary catheterisation is linked to a high incidence of catheter associated urinary tract infections (CAUTIs), but taking appropriate action may reduce CAUTIs by 33%. Four hundred and seventy seven patients with a long term urethral or supra pubic catheter are cared for by the local Continence service. Twenty two of the 477 patients were colonised with MRSA on their skin but with no signs of clinical infection. Six patients of the 22 had a history of a positive result for MRSA in the urine.

Methods and Measurement

It was agreed to use an antimicrobial solution instead of saline solution to clean the meatus before urinary catheterisation. The antimicrobial selected needed to have a broad antimicrobial efficacy, be non-irritating, available for single use and cost no more than saline.

Octenilin® cleaning solution sachets (an octenidine based antimicrobial solution) met these criteria. Octenidine is a broad-spectrum antimicrobial active against Staphylococcus aureus, Staphylococcus epidermidis, Proteus mirabilis, Streptococcus pyogenes, Klebsiella pneumoniae, Escherichia coli, Pseudomonas aeruginosa and Candida albicans.

To provide a benchmark, all patients with an indwelling urethral or supra pubic catheter were screened for MRSA in the urine before catheterisation and before the use of Octenilin solution.

After twelve months, the data will be analysed looking at MRSA in the urine and at the catheter site. Rates of E. coli and Klebsiella will also be monitored.

Evidence of Improvement

Early results have been promising. After nine months of antimicrobial solution use, patients have not developed UTI issues post catheterisation. Three patients who had previously tested positive for MRSA (before switching to the antimicrobial solution) continue to be MRSA negative when screened after catheterisation.

Future Steps

Data will continue to be collected and analysed. The community urinary catheterisation protocol incorporating the antimicrobial solution will provide the starting point for the development of a hospital tool.

Abstract ID: 2895

A time limited audit to measure the prevalence of meticillin-resistant Staphylococcus aureus (MRSA) in 10 nursing homes over 6 months and to determine whether application of topical decolonisation agent was an effective intervention to reduce the burden of MRSA within the homes

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Introduction

It has been reported that the risk of invasive infection following Meticillin-resistant Staphylococcus aureus (MRSA) colonisation increases between four to fifteen fold. The incidence of MRSA colonisation within care homes is unknown in our local population.
Method
A proactive approach to MRSA screening and decolonisation was adopted with the Clinical Commissioning Groups (CCG) and acute trust working together. An Infection Prevention and Control Nurse carried out nasal swabbing of the care home residents to ensure a consistent approach adopted. If a resident was found to be MRSA nasal positive they were prescribed a 5 day course of topical treatments. A follow-up screen 2-3 days post treatment was carried out to determine if the treatment was successful. If a resident remained positive, a second course of treatment was prescribed.

Results
In total, there were 799 MRSA swabs taken during the two completed surveillance periods which were 3 months apart. This consisted of 390 in the first prevalence and 409 in the second prevalence. The MRSA prevalence for the first screen was 10.3% and 6.8% for the second. Forty % of MRSA positive screens from the first prevalence were detected in residents who had a previous history of MRSA colonisation making this a significant risk factor. Patients were treated with Prontoderm® body foam and Mupirocin® nasal gel and had a clearance rate of 80% after one application. By the end of the second surveillance period the overall clearance rate was 100% demonstrating the intervention of decolonisation was effective.

Discussion
This audit demonstrated that a simple approach requiring limited resources can significantly reduce the burden of MRSA. Following the positive results a long term proactive screening regime for nursing and residential homes has been adopted within the health community, based on an ‘at risk criteria’, which includes residents with wounds, devices, new residents and recent hospital discharge.

Abstract ID: 2925
Knowledge, attitude and practices regarding personal hygiene of food handlers in Kuala Lumpur, Malaysia: A pilot study
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Introduction
Foodborne diseases have caused a significant morbidity and mortality around the world. Food safety is an increasingly important public health issue since years ago until now. Food handlers have a major role in the prevention of food poisoning during food production and distribution. However, food contamination by food handlers could occur and leading to foodborne diseases if they lack knowledge and neglect of their personal hygiene on food handling practices in their premises. This study was aimed to assess the level knowledge, attitude and practices among food handlers in Kuala Lumpur.

Methods
A cross sectional study was carried out on 30 food handlers. The information consisting of demographic, knowledge, attitude and practices on personal hygiene was collected using self-administered questionnaire.

Results
Overall results showed that the majority of the food handlers had a good knowledge, attitude and practices on personal hygiene. Analyzed data obtained stated that mean score for knowledge is 2.84±0.10 out of total 3 respectively, attitude is 4.38±0.25 and practices is 4.37±0.68 out of total 5 respectively.

Discussion
This study revealed that, although food handlers personal hygiene knowledge, attitude and practices were good, some of the hygiene aspects need to be emphasized. However, more effort is needed such as continuous education and food safety training should be provided periodically and frequently in order to minimize foodborne hazards.

Abstract ID: 2935
MRSA care in the community—why education matters
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Introduction
In primary care, patients are prescribed decolonisation treatment to eradicate meticillin-resistant Staphylococcus aureus (MRSA). This complex treatment process requires the patient to apply a topical antimicrobial treatment as well as adhering to rigorous cleaning regimes to ensure the environment is effectively managed. Patients have to apply treatment correctly in order for it to successfully eradicate MRSA from the skin. Patients need adequate information about this to allow them to complete the treatment regime effectively.

Methods
A pilot study was carried out which involved developing an enhanced nurse-delivered education tool, training a community nurse to use it, and then testing its use with a patient. Three interviews were carried out: one with a patient who received usual care, one with a patient who received the enhanced education and one with the community nurse who delivered the enhanced education tool.

Results
The patient who received the enhanced education reported better knowledge and understanding of the application of treatment and ways in which they could prevent the spread of MRSA compared with the patient who did not receive the enhanced education.

Discussion
This study compared one patient who had received enhanced education, with one who had not. This study suggests improved knowledge around MRSA for
both the community nurse and the patient and is therefore more likely to ensure treatment is both adhered to and effective. The interviews highlighted that providing patients with topical treatment regimens is not enough. More detailed information about how and when to use the treatment and the importance of maintaining a clean environment is an essential part of the treatment and is likely to make an important contribution to treatment outcomes. This pilot study highlights the need for further research to establish more effective ways to educate patients around the management of MRSA in primary care.

Abstract ID: 2943

Ulcerative keratitis: Lifestyle, other risk factors and treatment outcome

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Introduction

Ulcerative keratitis can be caused by infectious and noninfectious factors, potentially leading to significant visual morbidity. Regardless of the underlying etiology, it may be complicated by secondary microbial infections, which contribute further to disease burden and worsening prognosis. As in many cases the disease and its complications can be preventable, understanding, detecting and managing it promptly is critical.

The aim of the study was to identify the predisposing risk factors in patients with corneal ulcers and evaluate the management outcome.

Methods

The medical records of patients with signs and symptoms of ulcerative keratitis within a one-year period (2013-2014) were reviewed retrospectively. Age, gender, socioeconomic status, ophthalmological and other medical history, contact lens wear and smoking as potential risk factors were evaluated.

Results

A total of 27 patients (16 males, 11 females), with mean age 52 years, all high school graduates, were enrolled to the study. None of them received treatment prior to hospital visit. Trauma was detected in 32% of them. The percentage of contact lens wearers was 23%, while 15% had a medical history of herpetic keratitis, 13% had bullous keratopathy and 5% history of corneal transplant. Twenty eight of the participants were smokers. The location of corneal ulcer was central in 48% of them. In 13% of the cases an organism was identified in corneal scrapings, apart from a patient with history of keratoplasty, whose eye was subsequently enucleated. There was a positive correlation between trauma and contact lens wear with gender (male) and age (young patients).

Discussion

Trauma and contact lens wear are the most important risk factors for corneal ulcers. Public health education about the potential visual loss, preventative measures and significance of timely and appropriate intervention is recommended as prognosis can be good.

Abstract ID: 2944

Acknowledging a rare cause of herpes simplex reactivation resulting in keratitis: report of an interesting case

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Introduction

Glaucma is one of the leading causes of preventable blindness and prostaglandin analogues have been used widely in its therapy. There have been few case reports in the literature suggesting the potential association between the topical use of prostaglandin analogues and herpes simplex virus (HSV) recurrence causing keratitis. We present a case of HSV keratitis reactivation following the instillation of tafluprost for glaucoma management, and the lessons learnt.

Methods

A 65 year old female patient attended the outpatient glaucoma clinic of our hospital complaining of blurred vision, pain, redness, tearing, photophobia and foreign body sensation in her right eye. She had been under the care of the same clinic after being diagnosed with ocular hypertension and increased risk for glaucoma. She had been treated with prostaglandin analogue (first line treatment) for a week before the development of the above mentioned symptoms. The patient’s past medical history was insignificant for immune system disorders, other infections, receipt of immunosuppressant medications or corticosteroids.

Results

The slit lamp examination revealed a linear-branching dendritic ulcer with characteristic terminal buds, located centrally, stained well with fluorescein. Accompanied by reduced corneal sensation, which is pathognomonic of HSV corneal infection. Prostaglandin analogue was discontinued and treatment with antitherapeutic agents (acyclovir ophthalmic ointment 3% applied five times daily) and lubricants was initiated. After 2 weeks of therapy, the dendritic ulcer was resolved and the patient’s vision was restored to pre-event levels in 2 months’ time.

Discussion

It has been reported that the final pathway of HSV reactivation appears to be mediated by prostaglandins. Therefore, prostaglandin analogues should be prescribed with caution in patients with previous herpetic infections and especially those with history of HSV keratitis. Case reports like this can promote awareness between health care professionals for the unusual side-effects of commonly used medications.

Abstract ID: 2945

Unexplained intraocular inflammation, but not inexplicable: is syphilis the answer?

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Introduction

Syphilis, an infectious systemic disease that mimics various clinical entities, has re-emerged in several developed countries. The aim of the study is to present a case of acute, progressive visual loss caused by syphilitic intraocular inflammation and to highlight the importance of considering the ‘great imitator’ in the differential diagnosis of similar cases.

Methods

A 45 year old male was referred to our clinic from an ophthalmologist in private practice with the diagnosis of acute retinal necrosis possibly secondary to cytomegalovirus. He reported a 10-day history of acute, progressive visual loss in the left eye. Past medical and family history were unremarkable. The findings of the ophthalmological examination were as follows: best-corrected visual acuity (BCVA) 10/10 in the right eye and counting fingers at 30 cm in the left eye, anterior uveitis (hypopyon)/posterior uveitis (vitritis) and multiple retinitis foci. A thorough laboratory investigation including ANA, ANCA, RF, CMV IgG/IgM, HSV-1 and 2 IgG/IgM, VZV IgG/IgM, T. gondii IgG/IgM, HIV, CMV IgG/IgM, HSV-1 and 2 IgG/IgM, VZV IgG/IgM, T. gondii IgG/IgM, HIV, CMV IgG/IgM, HSV-1 and 2 IgG/IgM, VZV IgG/IgM, T. gondii IgG/IgM, HIV, CMV IgG/IgM, HSV-1 and 2 IgG/IgM, VZV IgG/IgM, T. gondii IgG/IgM, HIV was performed. Inpatient treatment with IV acyclovir and methylprednisolone was started.
Abstract ID: 2948

Optic neuritis in a young cattleman: Ocular brucellosis or multiple sclerosis?

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Introduction

Ocular brucellosis can affect any ocular structure and present with a variety of symptoms. Multiple sclerosis is a well-known cause of optic neuritis. Our purpose is to present a case of optic neuritis of unspecified etiology, with involvement of Brucella infection.

Methods

A 25-year-old male presented at the outpatient department of our hospital complaining of acute visual loss in his right eye with no associated symptoms and signs. He was a cattleman and his personal/family history was unremarkable.

Results

The results of the ophthalmological examination were: visual acuity of counting fingers in the right eye, positive relative afferent pupillary defect (RAPD), colour vision of 0/13 on Ishihara plates, normal anterior segment. Fundoscopy revealed inflammation of the optic disc vasculature with exudation of fluid into the peripapillary retina. These findings were compatible with acute neuroretinitis and optic neuritis confirmed by OCT examination. The rest of the clinical examination identified low-grade fever (37.5°C), liver and spleen enlargement and truck lymphadenitis. Blood laboratory tests detected an increased white cell count while both the Widal and Wright tests were positive, with the titer of the latter being >1:320. Blood cultures were negative for Brucella spp. MRI of brain and orbits showed few non-specific white matter lesions and isoelectric focusing of CSF detected oligoclonal bands, all suggestive of MS. The patient was treated with steroids IV (1g pulsed for 3 days and subsequent tapering) with a dramatic improvement of his ocular symptoms and signs. Systemic antibiotics (doxycycline) were also added to medication.

Discussion

Brucellosis remains an important health problem in many developing areas. Ocular involvement in brucellosis has been reported before. The signs and symptoms of it can be nonspecific, mimicking those of other diseases. Therefore, it should be taken into consideration in differential diagnosis of optic neuritis, especially in high-endemicity areas.

Abstract ID: 2950

Bilateral herpetic keratitis secondary to long-term immunosuppression – How to prevent the worst

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Introduction

Herpes simplex keratitis is, in general, a unilateral disease. But bilateral occurrence has also been reported especially in patients with compromised immune system. We report a case of a patient with Subcorneal Pustular Dermatosis (Sneddon and Wilkinson syndrome) who developed bilateral herpetic keratitis related to long-term immunosuppression.

Methods

A 78 year old female patient was admitted to the Department of Dermatology for the investigation of skin lesions, resulting in the diagnosis of Subcorneal Pustular Dermatosis (Sneddon and Wilkinson syndrome) and treatment with dapson. She developed haemolysis as a side effect of the above medication and she was started on corticosteroids. After 3 weeks of the initiation of corticosteroid treatment, the patient complained of blurred vision, pain, foreign body sensation, tearing and redness in both eyes and an ophthalmological evaluation was requested.

Results

The slit lamp examination revealed characteristic dendritic corneal ulcers in both eyes, which were suggestive of HSV keratitis. They were associated with reduced corneal sensation. The patient was treated with antiviral agents (acyclovir 3% ointment five times daily) and lubricants with a good outcome.

Discussion

Patients with systemic diseases on long-term corticosteroid treatment are immunosuppressed. Therefore, they are at high risk for reactivation of latent HSV infections. Although herpetic keratitis involving both eyes is rare, it is more often seen in patients who are immunocompromised. These patients should receive regular and thorough ocular examinations aiming for an early diagnosis and treatment of this condition.

Abstract ID: 2981

Championing infection control in care homes: the Anglia experience

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Improvement issue and context

Compliance with infection prevention and control standards in care homes are a marker of quality of care. In the past there was a large variation, from none to regular workshops, in provision of support and training for care home staff from different NHS organisations. From experience of managing communicable disease outbreaks and remedying inappropriately managed situations we have identified lack of training as the main underlying issue. There are over 600 registered care homes in our area.

Methods and measurement

1) To provide infection control training for care home staff. 2) To acquire a picture of existing training. 3) To introduce the concept of a Champion role. As well as a programme that would be of interest to staff attending and develop their knowledge, we wanted to introduce a picture of what already existed in the provision of infection control training. We also wanted to introduce the idea of an infection control champion in each home. We conducted 2 training events. A total of 118
staff attended. From workshop discussions we found a wide variation in infection control training provision, although most had this at induction and the majority had an annual refresher. Many reported in-house training; some private companies, several used e learning programmes or DVD. Quality was described as good to poor.

**Evidence of improvement**

High expectations were expressed re the Champion role and the level of influence and knowledge they would require. All staff expressed preference for face to face, group learning rather than e learning. The aim is a reduction in duration of outbreaks and number of exposed vulnerable individuals, potentially reducing complications arising from the illness, leading to a reduced burden on the wider health economy.

**Future steps**

Develop training programme for the Champion role. Maintain network of infection control Champions.
Implementation and impact of ultraviolet environmental disinfection in an acute care setting

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Key Words:
Clostridium difficile
Multiple-drug-resistant organisms

Background: Multiple-drug-resistant organisms (MDROs) and Clostridium difficile (CD) are significant problems in health care. Evidence suggests that these organisms are transmitted to patients by the contaminated environment.

Methods: This is a retrospective study of the implementation of ultraviolet environmental disinfection (UVD) following discharge cleaning of contact precautions rooms and other high-risk areas at Westchester Medical Center, a 643-bed tertiary care academic medical center. Incidence rates of hospital-acquired MDRO plus CD before and during the UVD use were evaluated using rate ratios and piecewise regression.

Results: The average time per UVD was 51 minutes, and machines were in use 30% of available time. UVD was used 11,389 times; 3,833 (34%) of uses were for contact precautions discharges. UVD was completed for 76% of contact precautions discharges. There was a significant 20% decrease in hospital-acquired MDRO plus CD rates during the 22-month UVD period compared with the 30-month pre-UVD period (2.14 cases/1,000 patient-days vs 2.67 cases per 1,000 patient-days, respectively; rate ratio, 0.80; 95% confidence interval: 0.73–0.88, P < .001).

Conclusion: During the time period UVD was in use, there was a significant decrease in overall hospital-acquired MDRO plus CD in spite of missing 24% of opportunities to disinfect contact precautions rooms. This technology was feasible to use in our acute care setting and appeared to have a beneficial effect.

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Multiple-drug-resistant organisms (MDROs) and Clostridium difficile (CD) are significant problems in health care. Evidence suggests that these organisms are transmitted to patients by the contaminated environment. Patients occupying a room that previously housed a patient with vancomycin-resistant Enterococcus (VRE) or methicillin-resistant Staphylococcus aureus (MRSA) or CD infection are at increased risk for acquisition of these organisms. Increased monitoring of cleaning procedures is associated with improved cleaning, less environmental contamination, and decreases in acquisition of VRE and MRSA.

Recently, supplemental methods for environmental disinfection, including ultraviolet light, have become available for use in patient care environments. Ultraviolet disinfection (UVD) technology uses either mercury bulb devices or pulsed xenon bulb devices. Rutala et al reported that mercury UVD reduced colony counts of MRSA and CD by more than 99% in test conditions and decreased both the number of positive cultures and the colony counts per positive culture when tested in rooms that had been occupied by patients with MRSA. Boyce et al also reported significant reductions in aerobic bacterial colony counts from bedside rails, over-bed tables, television remotes, bathroom grab bars, and patient bathroom toilet seats after using mercury UVD and significant reduction of CD spores with test plates located strategically in patient rooms. In both studies, objects and surfaces in direct line of sight were more effectively decontaminated by UVD than areas in shadow. Although these studies have demonstrated significant reductions of bacteria in vitro and in clinical settings, there are limited studies on patient outcomes or on the feasibility of use of mercury UVD in the health care environment.
Pulsed xenon UVD became available after mercury UVD. Literature to support the efficacy of pulsed xenon UVD in decreasing vegetative bacteria and bacterial spores indicates it is comparable with mercury UVD. In the first peer-reviewed study on patient outcomes, pulsed xenon UV was associated with a 53% decrease in CD cases in a community hospital, and preliminary data demonstrated an 80% to 90% decrease in CD room contamination and decreasing trends in CD infection and VRE colonization and infection among oncology patients. The purpose of this study is to describe the implementation of a pulsed xenon UVD system for environmental disinfection in an acute care setting and to quantify the rates of hospital acquired MDROs plus CD before and during UVD.

METHODS

This is a retrospective study of the implementation of UVD and the rates of hospital-acquired MDROs plus CD before and during the UVD use. The period before UVD was 30 months (January 2009-June 2011), and the UVD period was 22 months (July 2011-April 2013). This study was conducted at Westchester Medical Center, a 643-bed tertiary care hospital, near New York City. The hospital offers full services to adult and pediatric patients including specialized services for trauma, burn, neurosurgery, cardiothoracic surgery, transplant, and oncology.

The Infection Prevention and Control Department works collaboratively with Environmental Services, which is an outsourced department, to assure that cleaning protocols are appropriate. Bleach-based (sodium hypochlorite 0.55%) disinfectants are used daily and at discharge for all rooms occupied by adults. Pediatric rooms are disinfected daily using a quaternary ammonium compound; a sodium hypochlorite 0.55% disinfectant is used daily for contact precautions rooms and for all discharge cleaning. Most adult patient rooms outside of the intensive care units are double occupancy; all pediatric rooms are single occupancy. Patients with MDROs or CD receive care in a private room; are placed in a semiprivate room with the other bed blocked from occupancy, or are cohorted with another patient who harbors the same organism.

Pulsed xenon UVD (Xenex Corporation, Austin, TX) began in May 2011. In preparation for UVD use at our institution, we performed an assessment of the number and timing of contact precautions discharges and found the mean rate of contact precautions discharges was 0.87 per hour during peak discharge times of 2 p.m. to 6 p.m. These data guided the decision of how many machines would be needed. Two machines were leased with the primary goal of disinfecting contact precautions rooms upon patient discharge or transfer. Training of Environmental Services staff began in May, and UVD was in routine use in July of 2011. In addition to use for contact precautions discharges, UVD was used after end of day cleaning in the operating rooms, weekly in the dialysis unit, and for all burn unit discharges. UVD could be requested for rooms of long-stay patients or for discharges in units with high prevalence of MDRO or CD. In rooms with more than 1 occupant, UVD was deferred until the room was no longer occupied.

The UVD procedure was the following: The bed management system (Teletracking, Pittsburgh, PA) used text pagers to notify Environmental Services staff of room cleaning needs. This system (Teletracking, Pittsburgh, PA) used text pagers to notify Environmental Services further investigated the cause. During both the pre-UVD and the UVD periods, there were several initiatives to optimize environmental disinfection. Before UVD use, from July 2008 to December 2009, the hospital participated in the Greater New York Hospital Association CD initiative. This initiative required use of checklists for environmental cleaning and engaging the Environmental Services Department in assuring discharge cleaning was adequate. Mercury UVD (Lumalier, Memphis, TN) was used on a limited basis in the medical intensive care and burn units from January 2009 to June 2010. A new Environmental Services contractor began in January of 2011. Throughout this study, cleaning was monitored using supplemental methods; Adenosine triphosphate (3M Cleantrace; 3M, Minneapolis, MN) was used in 2010, and UV fluorescent tracking markers (Dazo; Ecolab, St. Paul, MN) were used in the 2011 to 2013 period. In September 2012, during the UVD period, a new discharge cleaning checklist was adopted for use by Environmental Services supervisors.

Other health care-associated infection reduction initiatives included public reporting of CD to the New York State Department of Health starting in January 2010 and a change from CD cytotoxin A–B enzyme immunoassay (Meridian Bioscience, Cincinnati, OH) to real-time polymerase chain reaction (Cepheid, Sunnyvale, CA) in July 2010. In addition, a randomized double-blind trial of chlorhexidine bathing was conducted on a single unit, and weekly intensive cleaning of occupied rooms in high-risk units occurred throughout both the pre-UVD and UVD periods.

Definitions

MDRO cases were patients with organisms recovered from clinical cultures that include MRSA, VRE, or gram-negative bacteria susceptible to 2 or fewer classes of antibiotics. CD cases were defined as cases with a stool diagnostic test positive for CD. MDRO or CD cases were considered hospital acquired if there was no history of the organism and the onset of symptoms that led to recovery of the organism was present after 3 days of hospitalization and not incubating at admission or recovered within 48 hours after discharge. Incidence rates of MDROs and CD were defined as new hospital-acquired cases per 1,000 patient-days. Rate data were abstracted from Infection Prevention and Control databases without any links to individual patient information. This study was a quality improvement initiative that assessed summary data without individual patient identifiers.

Data analysis

Descriptive statistics were used to report the number of UVD cycles completed, the reasons for use, the percent of contact...
precautions discharge rooms that received UVD, the total time used, the average additional time needed for UVD, and the total utilization of the 2 UVD machines. Rate ratios with corresponding 95% confidence intervals and tests for trends in rates were estimated using Poisson regression. To assess the difference between the incidence rate before and during UVD use, piecewise regression was used. The piecewise regression creates a combined model of the 2 time periods and compares the infection rates before and during UVD implementation. All data analyses were performed using Stata V.12.1 (StataCorp, College Station, TX).

RESULTS

UVD was performed 11,389 times from July 1, 2011, to April 30, 2013. Contact precautions discharges accounted for 3,833 (34%) uses, staff request for 3,695 (32%) uses, routine operating room and burn unit disinfection for 1,938 (17%) uses, and disinfection of bathrooms in occupied rooms accounted for 1,938 (17%) of uses.

Contact precautions rooms received UVD for 3,833 (76%) of discharges, with a range of 66% to 93% of discharges per month (Fig 1). The reasons for missed UVD upon discharge were miscellaneous 799 (67%) times, roommate was present 212 (18%) times, miscommunication with nursing 129 (11%) times, lack of availability of a machine 40 (3%) times, and because of urgent need for the room 9 (<1%) times.

UVD added an average of 51 minutes per discharge. This included approximately 31 minutes for arrival including setup of machine and setup of blackout curtains in areas that had open bays or glass windows and walls. UVD machines were in use for approximately 30% of the total time available. During the 22 months of UVD, changes were made to optimize utilization of the machines; these changes are summarized in Table 1.

The overall rates of hospital-acquired MDROs plus CD were stable for the 30 months before use of UVD ($P_{\text{trend}} = .89$) and for the 22 months during UVD ($P_{\text{trend}} = .28$) (Fig 2). However, the rate of hospital-acquired MDRO plus CD was significantly lower during the 22 months of UVD use compared with the 30-month period before UVD (2.14 cases per 1,000 patient-days vs 2.67 cases per 1,000 patient-days, respectively; rate ratio, 0.80; 95% confidence interval: 0.73-0.88, $P < .001$). The piecewise regression model showed a significant decrease in the infection rate during UVD use, $P < .001$. A subanalysis of the incidence rates of VRE, MRSA, CD, and resistant gram-negative bacteria demonstrated that each was significantly reduced during the UVD period (Table 2).

DISCUSSION

In this study, several implementation considerations were defined and monitored to optimize use of UVD. First, there was a method for automatically deploying the machines to contact precautions discharge rooms. In our hospital, the bed management system sends a text page that has the contact precautions message included. Second, a crucial factor was assuring availability of personnel to run the machines. Labor cost and availability must be considered in the budget and implementation plan for UVD. Our machines were in use 30% of the total available time in large part because of labor constraints, and labor constraints may have contributed to missing 24% of contact precautions discharge UVD opportunities. Staff is not primarily budgeted to run UVD; rather, this task is added onto the existing role of the staff or supervisor and may divert staff from other essential functions. Finally, our team discussed each contact precautions room missed on a weekly basis. This allowed us to uncover system flaws such as not assigning delivery of the UVD machines to a specific role at shift change, miscommunication in which Nursing told Environmental Services staff that UVD was not necessary, and unintended consequences such as deploying UVD to contact precautions rooms housing respiratory virus patients rather than only to those with MDROs and CD. It appears that UVD is feasible in our institution because it was cancelled less than 1% of the time because of immediate need for the room for patient care. Review of missed opportunities weekly has allowed us to improve our processes, although the need to evaluate utilization and missed opportunities is ongoing.

During the period of UVD, there was a 20% decrease in overall hospital-acquired MDRO plus CD. This statistically significant decrease in MDROs plus CD occurred in spite of missing 24% of...
opportunities for UVD of contact precautions rooms at discharge. Although there have been other studies of the effectiveness of UVD for reducing vegetative bacteria and CD spores from environmental surfaces, this study is among only a small number of studies evaluating rates of hospital-acquired pathogens in relation to the use of UVD.

The first clinical study in which UVD appeared to have a beneficial effect for reducing CD was reported by Sitzlar et al. They reported using UVD in a double occupancy room in a long-term care facility; 2 men acquired CD separately, but each had 2 recurrences of CD symptoms that were temporally associated. After treatment and UVD of the room, neither had further recurrences. This same group of investigators studied environmental contamination with CD spores after sequential interventions of feedback about cleaning, UVD, and supervised cleaning. They found that UVD decreased CD spore contamination in rooms but that cleaning was less rigorous during the UVD period. Supervised cleaning included the use of a 3-person dedicated daily disinfection team for high-touch surfaces in CD rooms and implementation of a process requiring that terminally cleaned CD rooms be "cleared" for the next patient by environmental services supervisors and/or infection control staff. In the period of supervised cleaning, CD spore contamination was eliminated by the cleaning, with no incremental benefit of UVD. In contrast, recent reports using a before and after design have associated UVD use with significant reduction in CD infection and VRE acquisition. The benefit of UVD versus standard

<table>
<thead>
<tr>
<th>Month/year</th>
<th>Change</th>
<th>Rationale</th>
</tr>
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<tbody>
<tr>
<td>8/2011</td>
<td>Environmental Services assigned the off-going supervisor to deliver the UVD machine to contact precautions rooms at change of shift.</td>
<td>To eliminate UVD misses at shift change.</td>
</tr>
<tr>
<td>9/2011</td>
<td>Contact precautions policy changed to require that patients who are eligible to have precautions stopped must be moved to a new room. Precautions are continued if they cannot be moved to a new room.</td>
<td>If precautions are discontinued and the patient remains in the room, the room will not be flagged for UVD at patient discharge.</td>
</tr>
<tr>
<td>4/2012</td>
<td>Discontinued use of UVD overnight in operating rooms.</td>
<td>A cleaning person was being diverted to run the UVD machine, resulting in a net loss of time dedicated to operating room cleaning.</td>
</tr>
<tr>
<td>5/2012</td>
<td>Routine use of UVD in bathrooms of occupied patient rooms added during non-peak discharge hours when staffing allowed.</td>
<td>Bathrooms are often highly contaminated, and it is feasible to use UVD in the bathroom with the door closed.</td>
</tr>
<tr>
<td>1/2013</td>
<td>Infection Prevention and Control is notified immediately if nursing told Environmental Services staff that UVD was not necessary.</td>
<td>Infection Prevention and Control can investigate communication breakdowns in real time and provide education to staff.</td>
</tr>
<tr>
<td>4/2013</td>
<td>Remove the isolation indicator that deploys UVD upon discharge from patients with respiratory viruses.</td>
<td>To maximize UVD availability for MDRO and CD room discharges.</td>
</tr>
</tbody>
</table>

Fig 2. Incidence of hospital-acquired multiple drug resistant organisms plus Clostridium difficile from January 2009 until April 2013.

Table 1
Timeline of ultraviolet disinfection use changes and rationale

<table>
<thead>
<tr>
<th>Month/year</th>
<th>Change</th>
<th>Rationale</th>
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<tr>
<td></td>
<td></td>
<td>For the management and treatment of patients with CD, the hospital implemented several changes to the current disinfection practices for contact precautions rooms.</td>
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</table>

Table 2
Rates of hospital-acquired multiple-drug-resistant organisms and Clostridium difficile before and during ultraviolet disinfection

<table>
<thead>
<tr>
<th>Organism</th>
<th>Before ultraviolet disinfection, 1/2009-6/2011</th>
<th>During ultraviolet disinfection, 7/2011-4/2013</th>
<th>Rate ratio, (95% confidence interval), P value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total</td>
<td>1,320</td>
<td>749</td>
<td>2.67 to 2.14</td>
</tr>
<tr>
<td>Vancomycin-resistant Enterococcus</td>
<td>443</td>
<td>257</td>
<td>0.90 to 0.73</td>
</tr>
<tr>
<td>Clostridium difficile</td>
<td>390</td>
<td>228</td>
<td>0.79 to 0.65</td>
</tr>
<tr>
<td>Methicillin-resistant Staphylococcus aureus</td>
<td>224</td>
<td>116</td>
<td>0.45 to 0.33</td>
</tr>
<tr>
<td>Multiple-drug-resistant gram-negative bacteria</td>
<td>260</td>
<td>148</td>
<td>0.52 to 0.42</td>
</tr>
</tbody>
</table>

Pt, patient.
cleaning and supervised “research” level cleaning is an area for further research.

In our study, overall decreases in MDRO plus CD were led by a decrease in VRE, which is our most common hospital-acquired MDRO. VRE has a large environmental reservoir; we and others1,2,3,4 have reported recovery of VRE from at least 23% to 25% of rooms housing infected or colonized patients. The importance of the environment as a potential source for VRE acquisition was demonstrated in a multivariate analysis in which VRE acquisition was significantly more likely if the prior occupant had VRE or if an environmental culture had been positive in the room.2,4 Hayden et al10 and Datta et al11 found decreased VRE acquisition following intensive monitoring of and feedback about housekeeping procedures. Although there were many other simultaneous infection control interventions occurring at our hospital during the period from 2009 until 2013 that could have contributed to the reduction in VRE acquisition, the rates experienced during the UVD period are the lowest incidence rates of VRE at our institution for the past 10 years25 and were sustained for 22 months.

The incidence rates of MRSA, CD, and MDR gram-negative organisms were also significantly lower during the UVD period. Although many simultaneous infection control initiatives could have contributed to these reductions, none appeared temporally associated with any reduction. For example, we had participated in CD reduction initiatives that included use of bleach-based disinfectants and cleaning checklists without any change in CD rates. Rates decreased during UVD use despite the transition to a more sensitive diagnostic test (polymerase chain reaction), which increased overall CD test positivity from 10% to 13%.

The limitations of this study include the before and after implementation of UVD design, which has inherent weaknesses, and the fact that this report is from a single institution. We did not evaluate antibiotic utilization, which can clearly affect acquisition rates of MDRO and CD. There were many simultaneous interventions occurring to reduce acquisition of MDROs and CD. However, the MDRO plus CD rates were stable for 30 months before initiation of UVD and only decreased during the first 6 months of the UVD period. These decreases were then sustained throughout the UVD period. Although the possibility of a cumulative effect of the multiple infection control interventions that were occurring during the pre-UVD period and continuing into the UVD period cannot be eliminated, our data suggest UVD use had an impact on these reductions.

Further study is needed to optimize the use of UVD and to further assess the effect of UVD use on acquisition rates of MDROs and CD. In addition, a cost-benefit analysis of UVD use that includes labor costs is also needed. Use of UVD as an adjunct to routine discharge cleaning of contact precautions rooms was feasible and temporally associated with a significant decrease in hospital-acquired MDRO plus CD in our institution.

Acknowledgment

The authors thank the Westchester Medical Center Environmental Services and Infection Prevention and Control Departments for their commitment to this project.

References

Brief report

Disinfecting personal protective equipment with pulsed xenon ultraviolet as a risk mitigation strategy for health care workers

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Key Words:
Environmental disinfection
Ebola
Personal protective equipment
Doffing process
Outbreak control
Ultraviolet

The doffing of personal protective equipment (PPE) after contamination with pathogens such as Ebola poses a risk to health care workers. Pulsed xenon ultraviolet (PX-UV) disinfection has been used to disinfect surfaces in hospital settings. This study examined the impact of PX-UV disinfection on an Ebola surrogate virus on glass carriers and PPE material to examine the potential benefits of using PX-UV to decontaminate PPE while worn, thereby reducing the pathogen load prior to doffing. Ultraviolet (UV) safety and coverage tests were also conducted. PX-UV exposure resulted in a significant reduction in viral load on glass carriers and PPE materials. Occupational Safety and Health Administration—defined UV exposure limits were not exceeded during PPE disinfection. Predoffing disinfection with PX-UV has potential as an additive measure to the doffing practice guidelines. The PX-UV disinfection should not be considered sterilization; all PPE should still be considered contaminated and doffed and disposed of according to established protocols.

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Low levels of contamination with Ebola virus are sufficient to infect a human host. 1 Personal protective equipment (PPE) protects health care workers by providing a physical barrier when caring for infected patients. However, a risk is created during the doffing of PPE because any error in this detailed process could result in the contamination of the health care worker’s hands or other part of their body. 2 Despite training and the use of an observer, 100% proficiency to successfully adhering to the Centers for Disease Control and Prevention’s (CDC’s) guidelines for PPE doffing cannot be expected at all times. 3,4 Fluorescent powder and other tracers are routinely used during training on the doffing process to demonstrate the presence of human error despite following these guidelines. 5 Furthermore, health care workers may be asked to don and doff PPE that they are unfamiliar with or have not received training on during emergency situations, increasing the likelihood of a doffing error.

This study examines the use of a pulsed xenon ultraviolet (PX-UV; Xenex Disinfection Services, San Antonio, TX) germicidal device as an additional process for disinfecting PPE prior to doffing as a risk mitigation strategy. The goal of this process is to reduce the probability of transmission in the event of a doffing error. PX-UV disinfection has been adopted by multiple hospitals for surface disinfection 6 and has demonstrated a reduction in the infection rates of Clostridium difficile, methicillin-resistant Staphylococcus aureus, and other multidrug-resistant organisms. 7-9 Ebola virus has...
a known sensitivity to germicidal ultraviolet (UV) light and is much more susceptible than hardy spores, such as C. difficile.\textsuperscript{10,11}

To determine the feasibility of PPE disinfection using PX-UV, the authors examined the following in a laboratory setting: (1) the effectiveness of PX-UV disinfection against an Ebola surrogate virus on a dry inanimate surface; (2) the effectiveness of PX-UV disinfection against PPE material inoculated with an Ebola surrogate virus; (3) the level of UV exposure for a person wearing PPE; and (4) the distribution of germicidal light coverage on PPE.

\textbf{MATERIALS AND METHODS}

The CDC and Environmental Protection Agency (EPA) recommend the use of hospital disinfectants with label claims for a nonenveloped virus (eg, norovirus, rotavirus, adenovirus, poliovirus) to disinfect environmental surfaces in rooms of patients with suspected or confirmed Ebola virus infection.\textsuperscript{12} Canine parvovirus (ATCC VR-2016), a nonenveloped virus not infective to humans, was selected as the surrogate organism for this research because it meets the CDC's and EPA's recommendations and was safe to the researchers involved in this study. The virus was diluted to obtain a concentration of viral solution. All samples were dried completely, and soft surface samples. Two and a half centimeters square segments were cut from the surgical gown and face shield and affixed onto glass carriers. As described previously, samples were inoculated with 0.02 ml volume in triplicate with triplicate controls and exposed to PX-UV for 5 minutes at 2 m.

For PPE disinfection, a plastic face shield (T5 hood with face shield; Stryker, Kalamazoo, MI) and a fluid-resistant gown (MicroCool gown; Kimberly-Clark, Irving, TX) were used as hard and soft surface samples. Two and a half centimeters square segments were cut from the surgical gown and face shield and affixed onto glass carriers. As described previously, samples were inoculated in triplicate with triplicate controls with the same volume and concentration of viral solution. All samples were dried completely, allowing the solution to soak into the absorbent material of the gown. Exposure was for 5 minutes at a 1-m distance from the PX-UV system.

Samples were harvested into a neutralization medium (2% fetal bovine serum Eagle's minimal essential medium), serially diluted, and plated onto host cells (dog tumor cells, ATCC CRL-1542). Plates were incubated for 6 days, and a secondary hemagglutination assay was performed to confirm the presence or absence of virus.

To determine the potential UV exposure to a health care worker through PPE, a spectrometer (USB2000 + XR; OceanOptics, Dunedin, FL) was used to determine the amount of UV light that penetrates the PPE material when it is 1 m away from the UV source. PPE should be worn according to well-accepted published protocols, with full coverage of skin and eyes.\textsuperscript{13} Final readings were compared with published standards of UV exposure limits recommended for safety purposes.\textsuperscript{14}

UV photochromatic stickers were placed on specific areas of the PPE to assess light distribution: clavicle area, shoulders, arms, chest, back, hips, legs, and shoe covers. The stickers were qualitatively assessed for color change to indicate a sufficient dose of germicidal UV light. The photochromatic stickers were used to assess reflectors designed to shorten the exposure time by collecting and redirecting light being emitted from the opposite side of the disinfection system.

\textbf{RESULTS}

Glass carriers, face shield, and gown material at 5.98 log per carrier demonstrated a $>4.00$ log reduction relative to respective time zero controls. Negative cell culture controls demonstrated no cytopathic effects (Table 1).

The spectral readings for UV light passing though the face shield and gowns were less than established UV exposure limits. The addition of the reflector allowed for increased redirection of light toward the person and effectively reduced the exposure time for PPE disinfection by half.

\textbf{DISCUSSION}

These results indicate that UV disinfection can be used to reduce the contamination levels of nonenveloped viruses in a controlled experimental environment on PPE material. This preliminary safety and effectiveness data could lead to further research investigating applications that include real-world PPE contamination of nonenveloped viruses, especially Ebola. To our knowledge, this is the first study where PX-UV disinfection has been shown to be effective on nonenveloped virus–contaminated PPE material. The distribution of UV light throughout the PPE, especially when used in conjunction with the UV reflector, provided useful information and should be a consideration in future research. Photochromic stickers, if placed prior to UV exposure, may be a method of validation of UV dose for use in real-world settings.

Prior to conducting experiments where study personnel would be in the same room with a functioning device, UV exposure measurements were taken through the PPE material to assure that personnel were not at risk. The study personnel who wore the PPE and stood in front of the device reported no adverse symptoms related to noise of the device or the light from the PX-UV bulb. Heat stress could be a factor during this process; however, the individual exposed to the process did not report excessive discomfort. Additional studies should consider multiple raters of brightness, sound, and heat factors during the process of PX-UV disinfection.

Whether PX-UV is similarly effective in reducing Ebola virus load on PPE, the extent to which bodily fluids obstruct the PX-UV efficacy, and whether this process leads to a decrease in transmission are future areas of investigation. Of course, these questions may be unanswerable because of the extreme rarity of Ebola transmission in the health care setting in the United States and the justifiably limited access to the Ebola virus for research purposes. Because the CDC and EPA have recommend hospitals using nonenveloped virus claims to be adequate markers of effectiveness against Ebola, we believe this preliminary data could be used by facilities interested in exploring additional decontamination methods.

It is well-documented that doffing is a risky process with the potential for causing infection. Hence, adding UV disinfection to the doffing process has the potential to provide an additional layer of safety for health care workers based on the data provided here. However, proper PPE selection, donning practices prior to patient care, and proper doffing processes are paramount to patient safety and cannot be compromised. Training on and adherence to established practices is the first priority for safety.

The addition of PX-UV disinfection does not replace any of the existing steps associated with doffing PPE, and special care should be taken with degloving because fluids on gloves may inhibit PX-UV disinfection. After PX-UV exposure, all PPE should still be treated as though it is contaminated and doffed and disposed of.

\begin{table}
\centering
\begin{tabular}{|c|c|c|}
\hline
Inoculated surface & Distance (m) & Log reduction (relative to respective time zero control) \\
\hline
Glass slide & 2 & 5.98 >4.00 \\
Face shield (PPE) & 1 & 5.98 >4.00 \\
Surgical gown (PPE) & 1 & 5.98 >4.00 \\
\hline
\end{tabular}
\caption{Effectiveness of PX-UV disinfection on different surfaces inoculated with canine parvovirus.}
\end{table}
according to the most current CDC protocol. No disinfection system will be able to completely eliminate the risk associated with doffing contaminated PPE.

Furthermore, only PX-UV disinfection has been validated in this study. We did not test low-pressure mercury-based germicidal light disinfection technology. More research into the uses of the PX-UV addition into any Ebola containment protocol could provide additional insight into these preliminary findings.

References

Major article

Evaluation of a pulsed xenon ultraviolet light device for isolation room disinfection in a United Kingdom hospital

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Key Words: Ultraviolet light decontamination hospital infection technology innovation patient flow

Background: Pathogen transmission from contaminated surfaces can cause hospital-associated infections. Although pulsed xenon ultraviolet (PX-UV) light devices have been shown to decrease hospital room bioburden in the United States, their effectiveness in United Kingdom (UK) hospitals is less understood.

Methods: Forty isolation rooms at the Queens Hospital (700 beds) in North London, UK, were sampled for aerobic bacteria after patient discharge, after manual cleaning with a hypochlorous acid–troclosene sodium solution, and after PX-UV disinfection. PX-UV device efficacy on known organisms was tested by exposing inoculated agar plates in a nonpatient care area. Turnaround times for device usage were recorded, and a survey of hospital staff for perceptions of the device was undertaken.

Results: After PX-UV disinfection, the bacterial contamination measured in colony forming units (CFU) decreased by 78.4%, a 91% reduction from initial bioburden levels prior to terminal cleaning. PX-UV exposure resulted in a 5-log CFU reduction for multidrug-resistant organisms (MDROs) on spiked plates. The average device turnaround time was 1 hour, with minimal impact on patient throughput. Ward staff were enthusiastic about device deployment, and device operators reported physical comfort in usage.

Conclusions: PX-UV use decreased bioburden in patient discharge rooms and on agar plates spiked with MDROs. The implementation of the PX-UV device was well received by hospital cleaning and ward staff, with minimal disruption to patient flow.

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Health care–associated infections are estimated to cost the UK National Health Service (NHS) £1 billion a year. Infecteds caused by multidrug-resistant organisms (MDROs) and other hospital–associated infections (HAIs) are associated with increased morbidity and mortality and are among the many challenges faced by hospitals striving for better patient safety. Despite the successes in the UK over the last decade in reducing the burden of some infections, such as Clostridium difficile infection and methicillin-resistant Staphylococcus aureus (MRSA) bloodstream infection, infection prevention and control continues to be challenging in hospitals. Austerity measures, increasing population demands for care, and emerging infection threats, such as from carbapenemase-producing Enterobacteriaceae (CPE), require innovative approaches to maintain quality and safety.

The environment provides a reservoir for pathogenic organisms and plays an important role in the transmission of infections, particularly in outbreak situations. Therefore, decontamination of patient care areas is now considered to be vital in a comprehensive infection prevention and control program and is critical in preventing transmission of norovirus and C difficile.

There may be significant variation in the way manual cleaning with chemicals is performed and its effectiveness, partly because of the complexity of the environment in which these activities take
place.\textsuperscript{6-8} For instance, a study showed that up to 50% of high-touch surfaces within patient areas are often missed during chemical cleaning because of inaccessibility and human error.\textsuperscript{9} Therefore, new technologies have begun to be investigated to help supplement the cleaning process with the intention of achieving better assurance of environmental decontamination.\textsuperscript{10-13}

Multiple no-touch disinfection devices have been developed for environmental decontamination, and many of these systems are being suggested for adoption in health care facilities in the United States as part of standard decontamination protocols.\textsuperscript{14,15} One such no-touch disinfection method involves ultraviolet in the C spectrum light-emitting devices, which use ultraviolet-C light between the wavelengths of 200 and 320 nm, the biocidal spectrum.\textsuperscript{16}

Pulsed xenon ultraviolet (PX-UV) light devices (Xenex, San Antonio, TX) have been described previously and studies in the United States indicate microbiologic efficacy of the PX-UV device,\textsuperscript{17-19} but the health care environment in the UK is challenging, with a decreasing hospital bed base and a need for faster patient discharges, less single rooms, and significant financial constraints. Therefore, the purpose of the current study was to evaluate the environmental efficacy and feasibility of using this no-touch technology within daily patient care activities in a UK hospital.

METHODS

This prospective study was conducted from July 2014–November 2014 at Queens Hospital (700 beds), a NHS hospital in the Barking, Havering, and Redbridge University Hospitals group in North London, UK, serving a population with a significant elderly proportion with many comorbidities. The study was approved by the hospital’s research board. A convenience sample of 40 hospital rooms was selected for this study. Three main outcomes were studied: microbiologic efficacy of the PX-UV device on aerobic bacterial counts, time taken for disinfection, and staff attitudes to the new technology.

Microbiologic efficacy

A comparative study was designed to evaluate the efficacy of the PX-UV device in reducing environmental contamination in postdischarge patient isolation rooms by sampling 5 high-touch surfaces before standard terminal cleaning, after standard terminal cleaning, and after PX-UV disinfection. Patient rooms were selected from acute medical assessment units A and B (there were 6 rooms in each unit). The study rooms were identified through the infection prevention and control database and were selected for use by infection prevention and control staff. The inclusion criteria specified for the study rooms were as follows: (1) it must have been a single occupancy room, (2) it must have been occupied for a minimum of 48 hours, (3) it must have been recently vacated on the same day as the sample collection, and (4) it must have been used as a contact isolation room.

Once the room was identified, baseline microbiologic samples were collected after patient discharge but before standard terminal cleaning. Five high-touch surfaces (bedrail, bathroom handrail, tray table, toilet seat, and bathroom faucet handle) were sampled using 5-mm diameter Trypticase Soy Agar contact plates (Oxoid, Basingstoke, UK). For flat surfaces the press plate method was used and for curved surfaces a rolling plate technique was used to ensure coverage of the appropriate surface area. After the initial sampling, hospital cleaners performed standard terminal cleaning, using a 1,000 ppm (0.1%) chlorine disinfectant (Actichlor Plus; Ecolab, Cheshire, UK), prepared using 1 effervescent tablet mixed with 1 L of water to produce a hypochlorous acid disinfectant solution with detergent (troclozone sodium). Once the terminal cleaning was completed and surfaces were dry, the second set of environmental samples was collected. Finally, the PX-UV device was deployed and then subsequent environmental samples were taken from the same 5 surfaces. PX-UV device operators and cleaning staff were blinded to the chosen sampling surfaces to prevent any bias or changes in cleaning practices. After sample collection, the Trypticase Soy Agar contact plates were returned to the laboratory, incubated in air at 37°C for 48 hours, and enumerated per the manufacturer’s recommendations with the number of colony forming units (CFU) being recorded. Aerobic bacteria, including MRSA, vancomycin-resistant enterococci (VRE), and CPE, will form colonies on Trypticase Soy Agar contact plates, but anaerobic bacteria such as C difficile will not.

In each hospital room, the PX-UV device was deployed for 3 cycles: two 5-minute cycles in the living room (1 cycle on each side of the patient bed) and one 5-minute cycle in the bathroom.

The efficacy of the PX-UV device was also evaluated by seeding agar plates with hospital clinical isolates of MRSA, VRE, multiresistant Acinetobacter, and CPE. Suspensions of each organism were produced by inoculating the isolate into 5 mL of saline to McFarland turbidity 0.5–1.0. The Miles and Misra method\textsuperscript{21} was used for dilution so that the CFUs postincubation could be counted by eye. Agar plates were divided into 6 equal sectors, and 20 μL of each dilution of organism was dropped onto the surface of separate sectors (ie, 1 agar plate had 6 dilutions for one of the test organisms.) Each drop was allowed to spread naturally, and plates were left upright on the bench to air-dry before inversion. In total, 3 sets of plates for each organism were prepared. One set of plates for each organism was immediately incubated once air-dried for 24 hours in air at 37°C as a control. The other 2 sets of plates for each organism were immediately taken to a sluice room (used for body fluid discard; also called a dirty utility room). The agar plates were placed at a surface 20 in above floor level adjacent to each other and at 1.2 m distance from the PX-UV device in the line of sight. One set of plates for each organism was kept covered (further control plate); the other was uncovered (test plate). All plates were exposed to PX-UV light for a 10-minute cycle. All plates were then incubated in air at 37°C for 24 hours.

Analysis of microbiologic samples

Means and frequencies described the total number CFU before and after standard terminal cleaning and after using the PX-UV device, overall and by surface location. Wilcoxon signed-rank tests were used to assess a change in CFU between baseline and after standard terminal cleaning for each surface location. Similarly, a change in CFU after standard terminal cleaning and after the PX-UV device use was assessed (Table 1). To examine a reduction in the presence of CFU with standard terminal cleaning versus no cleaning, or PX-UV disinfection versus standard terminal cleaning, the McNemar test was used to test the null hypothesis of marginal homogeneity. Evidence supporting the alternative hypothesis would suggest that one cleaning method was superior to the other (Table 2). For the seeded agar plates, CFU were recorded and CFU per milliliter were calculated (CFU/mL = number of colonies of a dilution × 50 × dilution factor).

Time studies

To determine the impact of the PX-UV device on isolation room decontamination times (and hence room availability), time studies of the movement and use of the device were conducted. A standard log was used to record when the device was collected from the storage area, how long the device was left waiting at the room before use, device in-use time, and device return time to storage.

Device transport time was standardized to represent the time it takes for the operator to walk from the storage area to the targeted...
Table 2
Proportion of samples with CFU present at baseline, after terminal cleaning, and after PX-UV disinfection, overall and by surface location (39 rooms)

<table>
<thead>
<tr>
<th>Surface location</th>
<th>No. of pairs</th>
<th>Baseline, n (%)</th>
<th>Terminal clean, n (%)</th>
<th>PX-UV, n (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Mean ± SD</td>
<td>P value*</td>
<td>Mean ± SD</td>
</tr>
<tr>
<td>Bedrail</td>
<td>28</td>
<td>16.2 ± 20.1</td>
<td>0.01</td>
<td>10 (35.7)</td>
</tr>
<tr>
<td>Tray table</td>
<td>39</td>
<td>9.6 ± 15.1</td>
<td>0.00</td>
<td>27 (69.2)</td>
</tr>
<tr>
<td>Bathroom handrail</td>
<td>39</td>
<td>11.6 ± 11.5</td>
<td>0.00</td>
<td>12 (30.8)</td>
</tr>
<tr>
<td>Toilet seat</td>
<td>39</td>
<td>31.2 ± 22.1</td>
<td>0.00</td>
<td>15 (38.5)</td>
</tr>
<tr>
<td>Bathroom faucet</td>
<td>39</td>
<td>36 (92.3)</td>
<td>&lt;0.01</td>
<td>27 (69.2)</td>
</tr>
<tr>
<td>Combined</td>
<td>184</td>
<td>1.7 ± 8.5</td>
<td>0.00</td>
<td>103 (56.0)</td>
</tr>
</tbody>
</table>

CFU, colony forming units; PX-UV, pulsed xenon ultraviolet.

Table 3
Description of CFU counts per sample

<table>
<thead>
<tr>
<th>Surface</th>
<th>Status</th>
<th>n (%), mean ± SD, median (min-max)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bedrail</td>
<td>Baseline</td>
<td>28, 16.2 ± 20.1, 9.0 (0-100)</td>
</tr>
<tr>
<td></td>
<td>Manual</td>
<td>28, 1.6 ± 3.9, 0.0 (0-20)</td>
</tr>
<tr>
<td></td>
<td>PX-UV</td>
<td>28, 0.5 ± 2.0, 0.0 (0-10)</td>
</tr>
<tr>
<td>Tray table</td>
<td>Baseline</td>
<td>39, 9.6 ± 15.1, 3.0 (0-70)</td>
</tr>
<tr>
<td></td>
<td>Manual</td>
<td>39, 2.6 ± 4.8, 0.0 (0-23)</td>
</tr>
<tr>
<td></td>
<td>PX-UV</td>
<td>39, 0.5 ± 2.7, 0.0 (0-10)</td>
</tr>
<tr>
<td>Bathroom handrail</td>
<td>Baseline</td>
<td>39, 11.6 ± 11.5, 9.0 (0-48)</td>
</tr>
<tr>
<td></td>
<td>Manual</td>
<td>39, 9.6 ± 22.6, 3.0 (0-100)</td>
</tr>
<tr>
<td></td>
<td>PX-UV</td>
<td>39, 1.5 ± 4.0, 0.0 (0-20)</td>
</tr>
<tr>
<td>Toilet seat</td>
<td>Baseline</td>
<td>39, 31.2 ± 22.1, 15.0 (0-100)</td>
</tr>
<tr>
<td></td>
<td>Manual</td>
<td>39, 12.4 ± 22.1, 3.0 (0-100)</td>
</tr>
<tr>
<td></td>
<td>PX-UV</td>
<td>39, 5.0 ± 17.3, 0.0 (0-100)</td>
</tr>
<tr>
<td>Bathroom faucet</td>
<td>Baseline</td>
<td>39, 27.9 ± 33.9, 15.0 (0-100)</td>
</tr>
<tr>
<td></td>
<td>Manual</td>
<td>39, 10.1 ± 15.4, 5.0 (0-70)</td>
</tr>
<tr>
<td></td>
<td>PX-UV</td>
<td>39, 0.8 ± 2.1, 0.0 (0-8)</td>
</tr>
<tr>
<td>Combined</td>
<td>Baseline</td>
<td>184, 19.5 ± 26.1, 10.0 (0-100)</td>
</tr>
<tr>
<td></td>
<td>Manual</td>
<td>184, 7.6 ± 16.8, 2.0 (0-100)</td>
</tr>
<tr>
<td></td>
<td>PX-UV</td>
<td>184, 1.7 ± 8.5, 0.0 (0-100)</td>
</tr>
</tbody>
</table>

CFU, colony forming units; max, maximum; min, minimum; PX-UV, pulsed xenon ultraviolet.

ward area with the PX-UV device. This transport time was recorded for every device deployment from storage facility to the target ward or room. In-room device use time was taken to also include any arranging of furniture. Of the sampled rooms, 31 had valid times recorded for each of the steps noted (Table 3).

Staff perceptions

A survey component was used to gauge staff attitudes toward the use of the new technology, including 3 device operators and 12 clinical ward staff members. Each of the surveys (one for operators and a separate survey for other staff) contained 4 Likert scale questions, ranging from responses of strongly disagree (or very difficult) to strongly agree (very easy). Agree-type responses (agree and strongly agree) were combined to denote whether or not staff agreed with the statement. Similarly, easy responses (easy and very easy) were combined to determine the ease of use for the PX-UV machine (Table 4). A type I error of α = 0.05 was assumed throughout. All analyses were performed using SAS version 9.2 (SAS Institute, Cary, NC).

RESULTS

Patient rooms

One room was discarded from analysis for not having PX-UV disinfection information, reducing the sample to 39 rooms. Table 1 provides a summary of the recovered bioburden from the patient environment postdischarge, after standard terminal cleaning, and...
after PX-UV disinfection for the surface locations of bed rail, tray table, bathroom handrail, toilet seat, and bathroom faucet. The greatest reduction was observed for the toilet seat (median reduction, 10 CFU; *P* < .01), followed by the bathroom faucet (reduction, 8 CFU; *P* < .01). The use of PX-UV disinfection further reduced bioburden for the tray table, bathroom handrail, toilet seat, and bathroom faucet. The greatest reduction with PX-UV disinfection after terminal cleaning was observed for the bathroom faucet (median reduction, 4 CFU; *P* < .01), followed by the bathroom handrail (reduction, 2 CFU; *P* < .01).

Both standard terminal cleaning and PX-UV disinfection after terminal cleaning appeared to be effective in the reduction of rooms with any CFU present (Table 2). The greatest proportion of contaminated rooms at baseline was observed for bed rail surfaces (93%), which was reduced the most after terminal cleaning to 36%. PX-UV disinfection after terminal cleaning appeared to further decrease the proportion of rooms contaminated by at least half for all 5 surfaces (ranging from 54% for the toilet seat to 82% for the tray table). Table 3 provides a description of CFU per sample. Average CFU for all sample sites were 19.5 (median, 10) CFU per contact plate (55 mm in diameter) at discharge. On standard terminal cleaning, average CFU per plate decreased 61% to 7.6 (median, 2) CFU per contact plate. After disinfection with the PX-UV device, the average CFU per plate decreased by 78% to an average of 1.7 (median, 0) CFU per plate, a 91% reduction from the initial levels.

### Spiked plates in the sluice room

The control plates incubated directly at 37°C in air showed confluent growth of colonies. Similarly, the covered inoculated plates that were exposed to PX-UV disinfection (the cover blocks exposure to PX-UV) as previously described also showed confluent growth; however, the plates that were not shielded from PX-UV disinfection showed 1 colony of MRSA, 6 colonies of VRE, 7 colonies of multidrug-resistant *Acinetobacter*, and 3 colonies of CPE, indicating a 5-log reduction in colony counts on exposure to PX-UV light in the sluice room.

### Time studies

Table 4 provides the time breakdown for specific tasks involved in PX-UV device use in room decontamination. The results recorded are from the perspective of the PX-UV device user and summarized by mean, median, and range. The median time for total PX-UV device deployment from retrieval to storage was 50 minutes. Retrieving and returning the device took approximately 5–6 minutes. Another 10 minutes were generally used for waiting to use the device. The actual PX-UV treatment time was approximately 20 minutes, which included rearranging furniture in the room and 3 locations for device use, taking up roughly one-third of the entire process.

### DISCUSSION

Increasingly, innovative no-touch disinfection devices are being used throughout health care arenas to provide more assurance of the cleanliness of hospital environments. The PX-UV device is one such no-touch disinfection device that is in use in the United States. However, there is limited published research on its implementation in the UK health care system. Our results demonstrate 3 main findings:

1. The failure of standard terminal cleaning (combined manual cleaning and chemical disinfection) of isolation rooms to adequately remove microbial contamination from the environment.
2. The PX-UV system significantly reduced microorganisms from common high-touch surfaces within patient isolation rooms and associated bathrooms.
3. The PX-UV device was easily incorporated into terminal decontamination protocols for isolation rooms within busy clinical areas and did not adversely affect patient throughput.

It is now accepted that a cleaner patient environment can reduce HAIs by reducing microbial contamination with less transmission of pathogens including MDROs to patients. This is of particular importance when considering an isolation room because a new occupant may acquire pathogens from the environment whose original source was a previous occupant. Our findings show that the initial bioburden recorded at 5 high-touch surfaces was reduced by terminal cleaning and further reduced by PX-UV application. When all sample locations were compiled, bioburden was reduced from a mean precleaning level of 19.5 CFU per contact plate to 7.6 after terminal cleaning and to 1.7 after PX-UV use, equivalent to a 61% reduction by terminal cleaning alone and a 78% reduction after PX-UV disinfection. The toilet seat and bathroom faucet showed the greatest reduction in bioburden overall. These findings could have particular significance when considering patients displaying symptoms of *C. difficile* infection because these high-touch areas would
be suspected to be contaminated with the bacteria and spores; however, C difficile was not investigated as part of this study. The activity of the PX-UV device against MDROs was undertaken in a sluice room where the environment was expected to be heavily contaminated prior to exposure, rather than a patient care area, as in another study, which could compromise patient safety through exposure to live cultures. There was a 5-log reduction in MDRO bacterial counts after the use of the PX-UV device for 10 minutes, highlighting the potential effectiveness against these significant causes of HAIs that could contaminate the hospital environment.

The enhanced level of disinfection was achieved during everyday hospital operations with negligible interruption to patient care and flow. Hospital cleaning staff were able to effectively incorporate the PX-UV device as a no-touch disinfection approach into daily routine practice. There are a few unique aspects to this study. Most previous studies conducted with PX-UV devices have been performed in the United States; this one however was conducted in the UK. This creates distinctive variables when compared with previous studies, including differences in hospital room layout, cleaning protocols, and hospital populations. With all of these local variables, the PX-UV device was shown to be effective at decreasing the bioburden in hospital isolation rooms. The results experienced in our study are similar to bioburden decrease seen in U.S. studies. The pressure for beds in the UK NHS also necessitates that isolation room decontamination must be both quick and effective to maintain patient flow without compromising patient safety. Therefore, rapid and effective decontamination of an empty patient room was a key consideration of hospital ward staff as part of this study, particularly when considering, generally, isolation rooms are fewer in number in UK hospital wards compared with the United States. Previous studies have discussed the time taken to run the device, but this study was able to record total retrieval to storage time as approximately 1 hour, with the PX-UV device use taking 20 minutes of the total time. The utilization of the device did not significantly increase the time taken to terminally decontaminate isolation rooms, and this was supported by the feedback from clinical ward staff with overall opinion of the device being relatively high—only 1 staff member reported that room turnaround time was affected on what were the most busy hospital wards.

Improvements could focus on strategic placement of devices to reduce transport time and nondisinfection and idle time if incorporated into standard hospital practice was considered. C difficile was not included as a specific pathogen in this study; when considering the demographics of the population the study hospital serves, this could provide valuable data. The use of the PX-UV device in multicounty ward settings should also be investigated, particularly in outbreaks when patients are cohorted into 4-6 patient occupancy ward bays. Our study is limited in the number of staff surveyed, and this is an area for future exploration. This study shows that no-touch, PX-UV device usage could be translated to a different health setting, which may bear consideration because MDROs pose an international threat.

References


Evaluation of a Pulsed-Xenon Ultraviolet Room Disinfection Device for Impact on Hospital Operations and Microbial Reduction

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This study evaluated the use of pulsed-xenon ultraviolet (PX-UV) room disinfection by sampling frequently touched surfaces in vancomycin-resistant enterococci (VRE) isolation rooms. The PX-UV system showed a statistically significant reduction in microbial load and eliminated VRE on sampled surfaces when using a 12-minute multiposition treatment cycle.

Infect Control Hosp Epidemiol 2011;32(3):000-000

Microbial contamination of surfaces in patient rooms has been well documented. Patients admitted to a room in which the previous occupant was colonized or infected with a pathogen requiring contact precautions have been shown to have an increase in the risk of acquiring that pathogen in intensive care units. The risk of vancomycin-resistant enterococci (VRE) acquisition increased if environmental room cultures were positive for VRE before patient admission. Numerous studies have shown that various types of enhanced cleaning methods can reduce the risk of acquiring multidrug-resistant pathogens that cause healthcare-associated infections (HAIs) and/or colonization.

UV irradiation in the spectrum between 200 and 320 nm deactivates microorganisms. Portable pulsed-xenon UV (PX-UV) germicidal irradiation produces broad-spectrum UV irradiation, including large amounts of energy in the germicidal spectrum (200–320 nm), by using a xenon gas flashlamp. It has been shown to be effective in deactivating a variety of pathogens, including endospores of Clostridium difficile, vegetative bacteria, and viruses.

The purpose of this study was to compare the use of a PX-UV disinfection system to the standard room terminal cleaning process and to assess (1) the level of room microbial contamination before and after applying each method and (2) the degree to which hospital operations (ie, room turnaround time) were affected by the use of each approach.

METHODS

Study setting and sampling. This comparative study was conducted at a large comprehensive cancer center from January to March 2010 and was approved as a nonhuman-subject, quality-improvement study by both infection control and materials use subcommittees. At the time of terminal cleaning, a research team went into 12 rooms, each approximately 14 m² with a separate bathroom, in which a patient had been under contact isolation for VRE infection or colonization for at least 2 days before discharge and took environmental surface samples. These samples were tested to determine bacterial heterotrophic plate counts (HPCs) and the presence of VRE. The frequently touched (high-touch) surfaces sampled included bed rails, tray tables, chair arms, telephones, cabinets, intravenous infusion poles, door handles, remote controls, toilet seats, bathroom handrails, and computers.

Three different sampling strata of high-touch surfaces were used in 4 rooms each to determine the effectiveness of PX-UV in uncleaned and cleaned environments: (1) 14 samples from high-touch surfaces were obtained before manual cleaning and after PX-UV treatment, (2) 14 samples from high-touch surfaces were obtained after standard terminal room cleaning was completed, and (3) 7 samples from high-touch surfaces were obtained before cleaning, after standard terminal cleaning, and after UV treatment.

Description of the device. The PX-UV device (Xenex Healthcare Services) contains a flashlamp operating at 2 Hz with an output of at least 24 W. It is approximately 48 × 40 × 100 cm and runs on 120 V. The flashlamp retreats into a heavy-duty case for wheeled transport by 1 person. The PX-UV device contains a UV feedback sensor for dose assurance, a 4-button control panel, a 30-second countdown, a remote control, and a door interlock. The PX-UV has been tested in independent laboratories against 22 organisms, including C. difficile endospores, methicillin-resistant Staphylococcus aureus, VRE, and Acinetobacter baumannii. The PX-UV device used is a certified “green” technology (Practice Greenhealth).

Room cleaning and disinfection protocols. The standard terminal cleaning for VRE isolation rooms was performed according to hospital guidelines, took approximately 30 minutes, and included the use of germicide (Wexcid; Wexford Labs). The PX-UV device was placed in 3 positions in the room and was run for 4 minutes in each position.

Environmental testing procedure. Samples from high-touch surfaces were taken using sterile swabs dipped in sterile 1:10 dilute Dey/Engley Neutralization Broth (BD) on a 6.5-cm² area for 30 seconds while using firm pressure. The swab samples were placed in 15-mL sterile centrifuge tubes filled with 5 mL of the neutralization and transport medium. These tubes were placed in a cooler on ice and shipped by overnight courier to Antimicrobial Test Laboratories (ATL), an independent contract microbiology laboratory in Round Rock, Texas. ATL was blinded to all sample identifiers until results had been reported. Samples were held at 4°C ± 2°C at the laboratory until plated within 4–24 hours of receipt to de-
termine bacterial HPCs. HPC analysis was conducted by plating the samples on R2A agar and incubating at room temperature for 5 days. VRE analysis was conducted by plating the samples on tryptic soy agar (TSA; BD) supplemented with 10 μg/mL vancomycin and incubating at 36°C ± 1°C for 48 hours. After aliquots were removed for quantitative plating, the collection tubes themselves were incubated for 24 hours at 36°C ± 1°C and then resampled and qualitatively tested for VRE by streaking a sample on TSA supplemented with vancomycin, as described above. Presumptive VRE isolates (after quantitative and/or qualitative analyses) were confirmed to be enterococci on the basis of a positive Gram stain with typical morphology and a negative catalase test result. Then, isolates’ vancomycin resistance was determined by Kirby-Bauer disk diffusion testing by using 1- and 30-μg disks.9

Hospital operational data. Time studies were conducted using a stopwatch to determine the time needed for PX-UV room treatment and for transport of the device within the hospital.

Statistical methods. Data were entered and analyzed using Stata (Statacorp). Descriptive statistics were calculated for HPC, VRE, and operational data. Because of the nonnormal distribution of the data, a nonparametric test, the Wilcoxon-Mann-Whitney test, was used to analyze the HPC data by room disinfection status.

Table 1. Comparison of Vancomycin-Resistant Enterococci (VRE) Detection and Bacterial Heterotrophic Plate Counts (HPCs), According to Room Cleaning Status

<table>
<thead>
<tr>
<th>Room status</th>
<th>No. (%) of samples</th>
<th>HPC, CFU/cm²</th>
<th>Mean (range)</th>
<th>Median (IQR)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>No. of samples</td>
<td>VRE positive</td>
<td>HPC positive</td>
<td></td>
</tr>
<tr>
<td>Before cleaning</td>
<td>75</td>
<td>17 (23.3)</td>
<td>57 (78.1)</td>
<td>33.0 (0–328.6)</td>
</tr>
<tr>
<td>After standard terminal cleaning</td>
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<td>4 (8.2)</td>
<td>58 (63.7)</td>
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</tr>
<tr>
<td>After pulsed-xenon ultraviolet treatment</td>
<td>75</td>
<td>0 (0)</td>
<td>27 (36.0)</td>
<td>1.2 (0–14.7)</td>
</tr>
</tbody>
</table>

Results

Two hundred thirty-nine samples were obtained from 21 surfaces from 12 rooms from which patients with VRE colonization and/or infection were discharged. The mean HPC for before cleaning, after cleaning, and after UV treatment was 33.0, 27.4, and 1.2 CFU/cm², and the number of VRE-positive surfaces was 17 (23.3%), 4 (8.2%), and 0 (0%), respectively (Table 1). Of the 18 VRE samples that were analyzed quantitatively, the mean VRE count was 19.5 CFU/cm² (range, 0.3–155.0; median, 40 [interquartile range, 0.8–27.1]). The Wilcoxon-Mann-Whitney test showed that if HPC was used as an outcome, each disinfection stage showed a statistically significantly improvement over the prior stage (Table 2).

The total time from when hospital dispatch called for room cleaning to when the room was ready for the next patient admission was 18 minutes and 48 seconds, with the total in-room time of 15 minutes following standard terminal cleaning.

Discussion

The study shows that use of PX-UV is more effective than standard manual room terminal cleaning in reducing the room’s microbial burden and reducing levels of known pathogens. We found statistically significantly lower HPCs and no VRE in rooms after PX-UV treatment, suggesting that the

Table 2. Impact of Standard Cleaning and Pulsed-Xenon Ultraviolet (PX-UV) Disinfection on Room Bacterial Heterotrophic Plate Count (HPC)

<table>
<thead>
<tr>
<th>Room status</th>
<th>No. of samples</th>
<th>HPC mean, CFU/cm²</th>
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<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Comparison 1</td>
<td></td>
<td></td>
<td>2.638</td>
<td>.0083</td>
</tr>
<tr>
<td>Before cleaning</td>
<td>73</td>
<td>33.0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>After standard terminal cleaning</td>
<td>91</td>
<td>27.4</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Comparison 2</td>
<td></td>
<td></td>
<td>6.430</td>
<td>&lt;.0001</td>
</tr>
<tr>
<td>Before cleaning</td>
<td>73</td>
<td>33.0</td>
<td></td>
<td></td>
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<tr>
<td>After PX-UV treatment</td>
<td>75</td>
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<tr>
<td>Comparison 3</td>
<td></td>
<td></td>
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risk to the next occupant from environmental contamination is correspondingly lower.

Our data show that the PX-UV disinfection system tested for the study is quick enough to be integrated into daily hospital operations without adversely affecting patient throughput.

Our study was not designed to address the impact of PX-UV treatment on HAI risk. Nevertheless, the clinical significance of improved room disinfection can be inferred from previous studies where enhanced room-cleaning protocols were used. It would be reasonable to assume that the PX-UV device, by significantly reducing room microbial contamination, would similarly (if not more markedly) improve patient safety and reduce HAI risk. However, prospective studies are needed to translate these promising environmental microbiological data into documentation that the PX-UV device can reduce HAI and colonization rates.

ACKNOWLEDGMENTS

Financial report. Funding for laboratory analysis was provided by Xenex Healthcare Services.

Potential conflicts of interest. M.S. and J.S. are shareholders in Xenex Healthcare Services. All other authors report no conflicts of interest.

Affiliations: 1. Xenex Healthcare Services, Austin, Texas; 2. Antimicrobial Test Laboratories, Round Rock, Texas; 3. Environmental Health and Safety, University of Texas MD Anderson Cancer Center, Houston, Texas; 4. Department of Infectious Diseases, Infection Control, and Employee Health, University of Texas MD Anderson Cancer Center, Houston, Texas.

Address reprint requests to Mark Stibich, PhD, MHS, 1250 South Capital of Texas Highway, Austin, TX 78746 (mark.stibich@xenex.com).

Received June 17, 2010; accepted August 18, 2010; electronically published February 4, 2011.
Evaluation of a Pulsed-Xenon Ultraviolet Room Disinfection Device for Impact on Hospital Operations and Microbial Reduction

Mark Stibich, PhD, MHS; Julie Stachowiak, PhD, MPH, MIA; Benjamin Tanner, PhD; Matthew Berkheiser, MS; Linette Moore, MS; Issam Raad, MD; Roy F. Chemaly, MD, MPH

This study evaluated the use of pulsed-xenon ultraviolet (PX-UV) room disinfection by sampling frequently touched surfaces in vancomycin-resistant enterococci (VRE) isolation rooms. The PX-UV system showed a statistically significant reduction in microbial load and eliminated VRE on sampled surfaces when using a 12-minute multiposition treatment cycle.

Infect Control Hosp Epidemiol 2011;32(3):000-000

Microbial contamination of surfaces in patient rooms has been well documented. Patients admitted to a room in which the previous occupant was colonized or infected with a pathogen requiring contact precautions have been shown to have an increase in the risk of acquiring that pathogen in intensive care units. The risk of vancomycin-resistant enterococci (VRE) acquisition increased if environmental room cultures had been reported. Samples were held at in a cooler on ice and shipped by overnight courier to Antimicrobial Test Laboratories (ATL), an independent contract microbiology laboratory in Round Rock, Texas. ATL was blinded to all sample identifiers until results had been reported. Samples were held at 4°C ± 2°C at the laboratory until plated within 4–24 hours of receipt to de-

METHODOLOGY

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Three different sampling strata of high-touch surfaces were used in 4 rooms each to determine the effectiveness of PX-UV in uncleaned and cleaned environments: (1) 14 samples from high-touch surfaces were obtained before manual cleaning and after PX-UV treatment, (2) 14 samples from high-touch surfaces were obtained after standard terminal room cleaning was completed, and (3) 7 samples from high-touch surfaces were obtained before cleaning, after standard terminal cleaning, and after UV treatment.

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**Results**

Two hundred thirty-nine samples were obtained from 21 surfaces from 12 rooms from which patients with VRE colonization and/or infection were discharged. The mean HPC for before cleaning, after cleaning, and after UV treatment was 33.0, 27.4, and 1.2 CFU/cm², respectively (Table 1). The Wilcoxon-Mann-Whitney test showed that if HPC was used as an outcome, each disinfection stage showed a statistically significantly improvement over the prior stage (Table 2).

**Discussion**

The study shows that use of PX-UV is more effective than standard manual room terminal cleaning in reducing the room’s microbial burden and reducing levels of known pathogens. We found statistically significantly lower HPCs and no VRE in rooms after PX-UV treatment, suggesting that the...
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REFERENCES

Evaluation of a Pulsed Xenon Ultraviolet Disinfection System for Reduction of Healthcare-Associated Pathogens in Hospital Rooms

**Article Overview**
The effectiveness of Xenex PX-UV for reducing *C. diff* spores, MRSA, VRE, and overall contamination in a hospital setting was investigated in uncleaned patient rooms, terminally cleaned patient rooms, and a controlled laboratory setting. Factors such as shading, pathogen concentration, and organic/protein load (gross contamination) were assessed and did not significantly impact the efficacy of the PX-UV device at reducing hospital room contamination. Lab-setting investigation showed log reductions lower than a continuous UV device; however, Xenex PX-UV was shown to reduce contamination effectively in real-world settings. The study notes that the Xenex Robot’s lack of hazardous mercury prevents dangerous handling and disposal concerns associated with all other UV devices.

The study demonstrated that organic burden present on real-world hospital surfaces, amount of pathogen present, and shading of light did not reduce the efficacy of Xenex PX-UV.

**Phase 1: Contamination Before and After Xenex (without terminal clean)**
In phase one, rooms did not previously house a *C.diff* patient, but *C.diff* was recovered

<table>
<thead>
<tr>
<th></th>
<th>MRSA (mean CFU)</th>
<th>VRE (mean CFU)</th>
<th>HPC (mean CFU)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Before</td>
<td>9</td>
<td>21</td>
<td>522</td>
</tr>
<tr>
<td>After</td>
<td>2</td>
<td>0</td>
<td>2</td>
</tr>
</tbody>
</table>

*Note a 99.6% drop in HPC despite lack of prior room cleaning*

**Phase 2: Contamination Before and After Xenex (with terminal clean)**
In phase two, 42% of rooms previously housed a *C.diff* patient

<table>
<thead>
<tr>
<th></th>
<th>MRSA (mean CFU)</th>
<th>VRE (mean CFU)</th>
<th>HPC (mean CFU)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Before</td>
<td>96</td>
<td>12</td>
<td>934</td>
</tr>
<tr>
<td>After</td>
<td>12</td>
<td>1</td>
<td>17</td>
</tr>
</tbody>
</table>

*Note a 98.2% drop in HPC*

**Additional comments by authors:**

1) “The PX-UV device has some important potential advantages over other UV disinfection devices. First, unlike continuous UV-C devices, xenon flash lamps do not contain mercury. Therefore, there are no safety hazards associated with disposal or exposure to mercury.”

2) “…the manufacturer recommends a relatively brief disinfection cycle (10-20 minutes per room versus up to 45 minutes for spore-killing cycles of some UV-C devices) which may facilitate greater use of the devices.”

3) “…it is possible that the organic burden present on real-world hospital surfaces might have less impact on the killing efficacy of PX-UV than UV-C.”

**Conclusion**
The PX-UV device reduced recovery of MRSA, *C. difficile*, and VRE on glass carriers and on frequently-touched surfaces in hospital rooms with a 10-minute UV exposure time. This study validates the Xenex PX-UV Robot’s real-world efficacy, and identifies shortcomings of other technologies.
Evaluation of a Pulsed Xenon Ultraviolet Disinfection System for Reduction of Healthcare-Associated Pathogens in Hospital Rooms


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DOI: 10.1017/ice.2014.36, Published online: 05 January 2015

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Evaluation of a Pulsed Xenon Ultraviolet Disinfection System for Reduction of Healthcare-Associated Pathogens in Hospital Rooms

Michelle M. Nerandzic, BS; Priyaleela Thota, MD; Thiveen Sankar C., MBA; Annette Jencson, MT, CIC; Jennifer L. Cadnum, BS; Amy J. Ray, MD; Robert A. Salata, MD; Richard R. Watkins, MD; Curtis J. Donskey, MD

OBJECTIVE. To determine the effectiveness of a pulsed xenon ultraviolet (PX-UV) disinfection device for reduction in recovery of healthcare-associated pathogens.

SETTING. Two acute-care hospitals.

METHODS. We examined the effectiveness of PX-UV for killing of Clostridium difficile spores, methicillin-resistant Staphylococcus aureus (MRSA), and vancomycin-resistant Enterococcus (VRE) on glass carriers and evaluated the impact of pathogen concentration, distance from the device, organic load, and shading from the direct field of radiation on killing efficacy. We compared the effectiveness of PX-UV and ultraviolet-C (UV-C) irradiation, each delivered for 10 minutes at 4 feet. In hospital rooms, the frequency of native pathogen contamination on high-touch surfaces was assessed before and after 10 minutes of PX-UV irradiation.

RESULTS. On carriers, irradiation delivered for 10 minutes at 4 feet from the PX-UV device reduced recovery of C. difficile spores, MRSA, and VRE by 0.55 ± 0.34, 1.85 ± 0.49, and 0.6 ± 0.25 log_{10} colony-forming units (CFU)/cm², respectively. Increasing distance from the PX-UV device dramatically reduced killing efficacy, whereas pathogen concentration, organic load, and shading did not. Continuous UV-C achieved significantly greater log_{10}CFU reductions than PX-UV irradiation on glass carriers. On frequently touched surfaces, PX-UV significantly reduced the frequency of positive C. difficile, VRE, and MRSA culture results.

CONCLUSIONS. The PX-UV device reduced recovery of MRSA, C. difficile, and VRE on glass carriers and on frequently touched surfaces in hospital rooms with a 10-minute UV exposure time. PX-UV was not more effective than continuous UV-C in reducing pathogen recovery on glass slides, suggesting that both forms of UV have some effectiveness at relatively short exposure times.

Infect Control Hosp Epidemiol 2014;00(0):1–6

Automated room disinfection technologies are increasingly being used as an adjunct to standard cleaning and disinfection in healthcare facilities. Ultraviolet (UV) radiation devices have been most widely adopted owing to the efficiency and well-documented efficacy of UV irradiation.1–7 Several UV room disinfection devices are now being marketed. Most of these devices use low pressure mercury gas bulbs, but recently pulsed xenon flash bulbs have also been incorporated into disinfection systems. UV radiation has peak germicidal effectiveness in the wavelength range from 240 to 280 nm.1–7 Mercury gas bulbs primarily emit UV-C at 254 nm, whereas xenon gas bulbs produce a broad spectrum of radiation that encompasses the UV (100–280 nm) and visible (380–700 nm) spectra.8–12 The UV-C radiation emitted by low pressure mercury bulbs is delivered in a continuous stream that gradually accumulates to lethal doses depending on duration of exposure and distance from the primary field of radiation.1–7 The broad-range UV delivered by xenon bulbs is emitted in short, high-intensity pulses, possibly requiring a shorter duration of exposure to achieve lethal doses.8–12

Given the increasing use of UV devices and variations in recommended cycle times, there is a need for evaluations of the real-world performance and comparative effectiveness of different devices. We previously demonstrated that a mobile, automated room disinfection device that utilizes mercury bulbs for emitting UV-C radiation is effective for reducing the frequency of positive methicillin-resistant Staphylococcus aureus (MRSA), vancomycin-resistant Enterococcus (VRE), and Clostridium difficile culture results on high-touch surfaces in hospital rooms (Tru-D Rapid Room Disinfection device; Lumalier).13 For disinfection of vegetative bacteria and C. difficile spores, the manufacturer recommends cycles in standard
hospital rooms of approximately 15 and 45 minutes, respectively. Here we examined the effectiveness of a mobile, automated pulsed xenon ultraviolet (PX-UV) device (Xenex; Xenex Disinfection Services) at a substantially shorter disinfection cycle (10 minutes, as suggested by manufacturer). The efficacy of the device was assessed for killing of MRSA, VRE, and \textit{C. difficile} spores on carriers placed in hospital rooms and for reducing naturally occurring contamination on high-touch surfaces in hospital rooms.

\textbf{METHODS}

\textbf{C. difficile, MRSA, and VRE Strains}

Two clinical isolates each of \textit{C. difficile}, MRSA, and VRE were studied. The MRSA strains were a pulsed-field gel electrophoresis type USA300 and USA800. The VRE strains were a VanA-type isolate (C37) and a VanB-type isolate (C68). The \textit{C. difficile} strains were VA 17, a restriction endonuclease analysis type BI strain, and VA 11, a restriction endonuclease analysis type J strain.

\textbf{Preparation of \textit{C. difficile} Spores}

Spores were prepared as previously described.\textsuperscript{14} Spores were stored at 4\degree C in sterile distilled water until use. Prior to testing, spore preps were confirmed by phase contrast microscopy and malachite green staining to be at least 99\% dormant, bright-phase spores.

\textbf{Microbiology}

VRE, MRSA, and \textit{C. difficile} were cultured on selective media as previously described.\textsuperscript{13,15} For specimens collected with sterile, premoistened swabs, the swabs were applied directly to the surface of the appropriate selective agar. To detect lower levels of \textit{C. difficile} spores, 10 mL of pre-reduced cycloserine-cefoxitin-brucella broth containing 0.1\% taurocholic acid and lysozyme 5 mg/mL (CDBB) was poured into a sterile culture tube containing specimens collected with sterile gauze pads.\textsuperscript{15} Positive broth cultures were subcultured onto selective agar for identification of \textit{C. difficile}. To quantify total heterotrophic bacteria, swabs were plated on trypticase soy agar containing 5\% sheep blood and incubated at 37\degree C for 48 hours. VRE and MRSA colonies with unique morphology were subjected to identification and susceptibility testing in accordance with Clinical Laboratories Standards Institute guidelines.\textsuperscript{16} \textit{C. difficile} was confirmed on the basis of odor and appearance of colonies and by a positive reaction using \textit{C. difficile} latex agglutination (Microgen Bioproducts).

\textbf{The Pulsed Ultraviolet Disinfection Device}

Figure 1 is a photograph of the PX-UV device (Xenex; Xenex Disinfection Services). The device contains a xenon gas flash bulb that operates at 2 Hz and emits a broad spectrum of radiation covering the UV-C spectrum of 200 to 280 nm as well as the visible light spectrum. The device is designed for manipulation by a single operator and is approximately 1.6 ft wide by 2.3 ft long by 3.3 ft high and weighs 150 pounds. It is operated remotely outside the room and includes motion sensors, which turn off the device if the door is opened. The device is wheeled into a strategic position located near high-touch surfaces in the room and set to irradiate for 5 to 7 minutes as suggested by the manufacturer. Then, the device is wheeled to a second location in the room and run for an additional 5 to 7 minutes. The disinfection process takes approximately 15 to 20 minutes, which includes setup, radiation cycles, and repositioning.

\textbf{The Impact of Pathogen Concentration and Organic Load on the Efficacy of PX-UV Disinfection on Carriers in Hospital Rooms}

Initial experiments were conducted to determine whether pathogen concentration (ie, colony-forming units [CFU] per \text{cm}^2) or organic load influenced the disinfection efficacy of the PX-UV device. Ten \mu L aliquots of \textit{C. difficile} spores, MRSA, and VRE suspended in phosphate buffered saline were inoculated onto glass microscope slides and spread to cover a 1-\text{cm}^2 area. For each pathogen, the inoculum applied to the slide was adjusted such that 2 to 5 or more \log_{10}CFU/cm^2 were recovered from the positive control specimens after desiccation. For a subset of samples, the organisms were suspended in 5\% fetal calf serum.

The slides were placed on a table positioned centrally over the bed in a hospital room, 4 feet within the direct field of radiation delivered by the PX-UV device. Baseline slides were left untreated outside of the room (ie, positive controls). The PX-UV device was run for a total of 10 minutes, 5 minutes on the left side of the bed and 5 minutes on the right, as suggested
by the manufacturer and standard protocol in the facility utilizing the device.

To quantify viable organisms, the slides were submersed in 25 mL of sterile phosphate buffered saline and vortexed vigorously, and dilutions of the suspensions were plated onto selective media. Following 48 hours of incubation, log_{10}CFU reductions were calculated by comparing the log_{10}CFU recovered from slides after PX-UV disinfection to untreated controls. All experiments were performed 3 times.

The Impact of Distance on the Efficacy of PX-UV Disinfection on Carriers in Hospital Rooms

The killing efficacy of the PX-UV device was evaluated at increasing distances from the primary field of radiation. Slides were prepared as described previously. However, the inoculum was altered such that each glass slide yielded 5 log_{10} CFU at baseline. Additionally, slides were placed 4 feet, and 10 feet within the direct field of radiation, and also 4 feet shaded from direct radiation (under bedside table).

Comparison of Pulsed Xenon Versus Continuous Mercury UV for Killing of Pathogens

We compared the efficacy of PX-UV versus UV-C delivered by mercury bulbs for reduction of pathogens inoculated onto slides in similarly sized hospital rooms. This comparison was performed in separate facilities because the devices were housed in separate hospitals. The experiments were performed in similar rooms with equivalent dimensions, and the experimental samples were placed at the same distances from the UV devices. Slides were prepared as described previously; the inoculum was altered such that each glass slide yielded 5 log_{10} CFU at baseline. The slides were placed 4 feet from each device within the direct field of radiation. The UV-C was delivered by the Tru-D device (Lumalier); each device was run for a total of 10 minutes. Slides were processed as described previously. The experiments were performed 3 times.

Disinfection of Environmental Surfaces in Hospital Rooms

The efficacy of the PX-UV device was assessed in rooms (~10 × 20 feet) of discharged patients in a tertiary care facility. In phase 1, the PX-UV device was run in rooms that had not yet been cleaned. In phase 2, the device was run after standard terminal cleaning by environmental services personnel that included use of bleach for high-touch surfaces in all discharge rooms; a subset of the rooms had previously been occupied by patients with *C. difficile* infection. Swabs and gauze pads pre-moistened with saline were used to collect cultures for MRSA, VRE, *C. difficile*, and total heterotrophic bacteria from high-touch surfaces (ie, call light, bedside table, telephone, chair, intravenous poles, portable keyboards, and bed rail) before and after use of the PX-UV device for 10 minutes (5 minutes on each side of the bed). An approximately 10 × 10-cm area was cultured before PX-UV disinfection and adjacent areas of the same size were cultured after disinfection. Specimens were cultured and identified as described previously.

Data Analysis

Data were analyzed using STATA, version 9.0 (StataCorp). Continuous data were analyzed using paired t tests and categorical data were assessed using the Fisher exact test.

RESULTS

Figure 2 shows the mean log_{10}CFU/cm² reductions of 2 strains of *C. difficile*, MRSA, and VRE on glass slides after the use of the PX-UV device. There were no significant differences between the log_{10}CFU reductions of the 2 strains of each pathogen tested. Therefore, in subsequent experiments, data for the 2 strains was pooled. Pathogen concentration did not have a significant impact on the killing efficacy of the PX-UV device. Irradiation delivered 4 feet from the PX-UV device for 10 minutes reduced *C. difficile* spores by 0.55 ± 0.34 log_{10}CFU/cm², MRSA by 1.85 ± 0.49 log_{10}CFU/cm², and VRE by 0.6 ± 0.25 log_{10}CFU/cm². Organic load (5% fetal calf serum) did not significantly impact the efficacy of the PX-UV device (data not shown).

As shown in Figure 3, the efficacy of PX-UV decreased as distance from the device increased. For each pathogen, significantly less reduction was achieved at 4 feet versus 6 inches and at 10 feet versus 4 feet (P < .05 for each comparison). At 4 feet from the device, shading the organisms from the direct field of radiation did not have a significant impact on efficacy (P > .05 for each comparison). At 10 feet from the device, the log_{10}CFU reduction was less than 1 log_{10}CFU/cm² for each pathogen.

Figure 4 shows the mean log_{10}CFU/cm² reductions of *C. difficile*, MRSA, and VRE on slides after the use of the UV-C and PX-UV devices for 10 minutes at a distance of 4 feet from the devices. The UV-C device achieved significantly greater log_{10}CFU reductions than the PX-UV device (P < .001 for each pathogen).

Table 1 provides a summary of the results of 2 phases of PX-UV disinfection on high-touch surfaces in hospital rooms. For 16 rooms that were cultured before and after use of PX-UV without cleaning (phase 1), PX-UV resulted in statistically significant reductions in the percentages of sites positive for each of the 3 pathogens, the number of CFU recovered for each pathogen, and the heterotrophic plate counts. For 24 rooms that were cultured before and after standard cleaning plus PX-UV (phase 2), there were also statistically significant reductions in percentages of sites positive for each of the pathogens, the number of CFU recovered, and the heterotrophic plate counts.

DISCUSSION

We found that the PX-UV device reduced recovery of MRSA, *C. difficile*, and VRE on carriers and on frequently touched
surfaces in hospital rooms with a 10-minute exposure time. Increasing the distance from the device dramatically reduced the killing efficiency of PX-UV irradiation, whereas pathogen concentration, organic load, and shading from the direct field of radiation did not. PX-UV was less effective than continuous UV-C in reducing pathogen recovery on glass slides with a 10-minute exposure time in similar hospital rooms. Our findings are consistent with previous studies demonstrating the efficacy of PX-UV disinfection for reduction of VRE, MRSA, and heterotrophic bacteria from surfaces in healthcare facilities.8,11 In addition, our study provides 2 assessments not included in previous publications on PX-UV (ie, log reductions achieved by PX-UV on carriers and a comparison with continuous UV). Although the log reductions achieved by PX-UV on carriers at 10 minutes were relatively modest, this exposure time was sufficient to reduce contamination on real-world surfaces. We have previously demonstrated that contaminated surfaces in hospital rooms yield relatively low concentrations (<1–3 log10 CFU per site sampled using swabs) of healthcare-associated pathogens.13,17 This observation is corroborated in the current study and may contribute to the efficacy of the PX-UV device in real-world settings.

The PX-UV device has some important potential advantages over other UV disinfection devices. First, unlike continuous UV-C devices, xenon flash lamps do not contain mercury.
Therefore, there are no safety hazards associated with disposal or exposure to mercury. Second, the manufacturer recommends a relatively brief disinfection cycle (10 – 20 minutes per room versus up to 45 minutes for spore-killing cycles of some UV-C devices) which may facilitate greater use of the devices. However, our results suggest that continuous UV-C devices might be similarly effective or more effective than PX-UV with a 10-minute exposure time. Moreover, previous studies have demonstrated that optimal killing of C. difficile spores by UV-C is likely to be achieved with longer cycle times, for 2 continuous UV-C devices, reductions in C. difficile spores at 10, 20, and 40 minutes of exposure were ~1, 2, and 3 log_{10}CFU, respectively. Finally, organic load did not impact the efficacy of the PX-UV device. PX-UV has previously been shown to be more effective at penetrating organic load present in waste water than UV-C emitted by low pressure mercury bulbs. Thus, it is possible that the organic burden present on real-world hospital surfaces might have less impact on the killing efficacy of PX-UV than UV-C. However, we have previously demonstrated that real-world organic material collected from hospital surfaces only modestly reduced the effectiveness of continuous UV-C for killing of C. difficile spores.

The PX-UV device also has some potential limitations. The efficacy of PX-UV was dramatically reduced as the distance from the device was increased. Therefore, it is recommended that commonly touched surfaces (eg, bedside table, call button, telephone) be arranged close to the device for optimal exposure to irradiation. Although the PX-UV device reduced contamination on surfaces, residual contamination was not uncommon. In contrast, technologies such as hydrogen peroxide vapor may be more effective in eliminating pathogens. Further studies are needed to determine whether the level of reduction in contamination provided by the PX-UV device is sufficient to reduce rates of infection. Two recent quasi-experimental studies have reported reductions in rates of C. difficile infection with the use of PX-UV. Randomized trials are needed to determine whether use of PX-UV or other UV devices is effective in reducing infection rates.

Our study has some limitations. First, the use of swabs and direct plating to quantify the concentrations of bacteria is imprecise at higher concentrations. In addition, recovery and release of bacteria from swabs is less than 100% and therefore we may not have detected lower levels of bacteria on surfaces. However, methods were standardized for processing all

![Graph](image_url)

**Figure 4.** The efficacy of pulsed xenon ultraviolet (PX-UV) versus continuous mercury UV-C for killing of pathogens.

A comparison of the log_{10}CFU reduction/cm² of Clostridium difficile spores, methicillin-resistant Staphylococcus aureus (MRSA), and vancomycin-resistant Enterococcus (VRE) by PX-UV and continuous mercury UV-C is shown. Carriers contained 5 log_{10}CFU of each pathogen. The carriers were irradiated for 10 minutes at a distance of 4 feet from the devices. The means of the data from experiments conducted in triplicate are presented. Error bars indicate standard error.

![Table](image_url)

**Table 1.** Clostridium difficile, Methicillin-Resistant Staphylococcus aureus (MRSA), Vancomycin-Resistant Enterococcus (VRE), and Total Heterotrophic Plate Counts (HPC) on Hospital Surfaces before and after Pulsed Xenon Ultraviolet (PX-UV) Disinfection

<table>
<thead>
<tr>
<th></th>
<th>C. difficile</th>
<th>MRSA</th>
<th>VRE</th>
<th>HPC</th>
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<tbody>
<tr>
<td><strong>Phase 1</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Before</td>
<td>13/112 (12),</td>
<td>11/112 (10)</td>
<td>4/112 (4),</td>
<td>107/112 (96)</td>
</tr>
<tr>
<td>After PX-UV</td>
<td>3/112 (3)b</td>
<td>1/112 (0.9)b</td>
<td>0/112 (0)b</td>
<td>2 (2)b</td>
</tr>
<tr>
<td><strong>Phase 2</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Before</td>
<td>22/113 (19)</td>
<td>11/113 (10)</td>
<td>4/113 (4),</td>
<td>56/86 (65)</td>
</tr>
<tr>
<td>After standard cleaning &amp; PX-UV</td>
<td>9/113 (8)a</td>
<td>2/113 (2),</td>
<td>1/113 (0.9),</td>
<td>934 CFU before, 17 after (98% drop)</td>
</tr>
</tbody>
</table>

**NOTE.** CFU, colony-forming units.

*a*Broth enrichment positive only, no data available for mean CFU.

*b*Indicates a significant reduction, *P* < .01.

In phase 2, a total of 42% of rooms housed patients with C. difficile infection (in phase 1, no rooms housed such patients).
samples so any limitations in the methodology would be equally shared by baseline and experimental groups. Second, because the PX-UV and continuous UV-C devices were housed in separate hospitals, it was not feasible to perform the comparative evaluation in the same room. We cannot completely rule out the possibility that some of the differences in results for the 2 devices were due to unappreciated differences in room characteristics. However, the experiments were performed in similar rooms with equivalent dimensions, and we found similar results for the PX-UV device when testing was done in 3 different rooms. Finally, for the evaluation of pathogen reduction in hospital rooms, we did not monitor the thoroughness of standard environmental disinfection practices.

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REFERENCES

Central Texas VA Medical Center

Central Texas VA Medical Center cleaned MRSA rooms with a thorough manual cleaning of all surfaces. They then cleaned another set of MRSA rooms for visible dirt only (a “quick clean”) and used Xenex Full Spectrum Disinfection™.

A quick clean + Xenex was

• 22% faster than manual clean
• 7x better at reducing microbes
• 12x better at reducing MRSA

Less time. Fewer chemicals.

99% MRSA reduction.

Evaluation of a pulsed-xenon ultraviolet room disinfection device for impact on contamination levels of methicillin-resistant *Staphylococcus aureus*

Chetan Jinadatha1*, Ricardo Quezada2, Thomas W Huber1, Jason B Williams3, John E Zeber1,2 and Laurel A Copeland1,2

**Abstract**

**Background:** Healthcare-acquired infections with methicillin-resistant *Staphylococcus aureus* (MRSA) are a significant cause of increased mortality, morbidity and additional health care costs in United States. Surface decontamination technologies that utilize pulsed xenon ultraviolet light (PPX-UV) may be effective at reducing microbial burden. The purpose of this study was to compare standard manual room-cleaning to PPX-UV disinfection technology for MRSA and bacterial heterotrophic plate counts (HPC) on high-touch surfaces in patient rooms.

**Methods:** Rooms vacated by patients that had a MRSA-positive polymerase chain reaction or culture during the current hospitalization and at least a 2-day stay were studied. 20 rooms were then treated according to one of two protocols: standard manual cleaning or PPX-UV. This study evaluated the reduction of MRSA and HPC taken from five high-touch surfaces in rooms vacated by MRSA-positive patients, as a function of cleaning by standard manual methods vs a PPX-UV area disinfection device.

**Results:** Colony counts in 20 rooms (10 per arm) prior to cleaning varied by cleaning protocol: for HPC, manual (mean = 255, median = 278, q1-q3 = 132–304) vs PPX-UV (mean = 449, median = 365, q1-q3 = 332–530), and for MRSA, manual (mean = 127; median = 28.5; q1-q3 = 8–143) vs PPX-UV (mean = 108; median = 123; q1-q3 = 14–183). PPX-UV was superior to manual cleaning for MRSA (adjusted incident rate ratio [IRR] = 7; 95% CI <1-41) and for HPC (IRR = 13; 95% CI 4–48).

**Conclusion:** PPX-UV technology appears to be superior to manual cleaning alone for MRSA and HPC. Incorporating 15 minutes of PPX-UV exposure time to current hospital room cleaning practice can improve the overall cleanliness of patient rooms with respect to selected micro-organisms.

**Keywords:** MRSA, Methicillin-resistant *Staphylococcus aureus*, No touch disinfection, Pulsed xenon ultraviolet disinfection device, Nosocomial infections

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Background
Healthcare-acquired infection (HAI) with methicillin-resistant \textit{Staphylococcus aureus} (MRSA) is a significant cause of mortality and morbidity in the United States accounting for up to $9.7$ billion annually in additional health care costs, and €44.0 million annually in Europe [1,2]. In the Americas, Europe, and parts of Africa and Asia, MRSA is the predominant multi-drug resistant microbe, making it a global concern of escalating importance in terms of cost and patient safety [3]. Combating MRSA with new pharmaceutical agents offers only short-term solutions; unconventional approaches may comprise a more effective solution to drug-resistant infectious microbes [4].

Patients admitted to rooms vacated by MRSA-positive patients have higher relative risk of acquiring MRSA [5,6]. In a 2009 review of environmental cleaning studies, Dancer concluded that high-touch surfaces present one of the biggest risks of MRSA acquisition for patients, providing a source of direct infection to patients and of indirect infection via healthcare workers [7]. Decontaminating high-touch surfaces could prevent HAI [8]. Manual cleaning with approved disinfectants is the current standard of disinfection in most countries including the United States, and this requires supervision with constant reinforcement and education of environmental management service (EMS) staff to maintain effectiveness [9].

Surface decontamination technologies that utilize ultraviolet light or hydrogen peroxide may be effective at reducing microbial burden, possibly with greater consistency than is achieved with manual methods [10-13]. Portable pulsed xenon ultraviolet (PPX-UV) technology uses high-intensity broad-spectrum UV irradiation in the 200–320 nm range. UV breaks the molecular bonds in DNA, thereby destroying the organism and spores in laboratory settings [12,14]. Spores from \textit{Clostridium difficile} (c.diff) are killed by 185–230 nm UV irradiation, overlapping the range of the PPX-UV [15].

The efficacy of PPX-UV in hospitals in comparison to manual cleaning has not been demonstrated. The purpose of this study was to compare standard manual room-cleaning to PPX-UV disinfection technology for MRSA and bacterial heterotrophic plate counts (HPC) on high-touch surfaces in patient rooms.

PPX-UV device
We used a portable PPX-UV device (Xenex Healthcare Services, San Antonio, TX) measuring 30 L × 20 W × 38 H inches (Figure 1). The device is used in empty patient rooms after discharge as prolonged exposure to UV can cause skin and eye irritation. The device used in this study housed a bulb twice as intense as in the device described by Stibich and colleagues [10], and it had new features such as a data logger, reflector, and UV pass filter. The data log recorded room number, user ID, time, date, number of pulses, amount of energy emitted and any error codes. The reflector was mounted on a column housing the xenon gas bulb emitting the pulsed UV rays. While column moved up and down during a 5-minute cycle, the reflector optimized the UV rays downward to high-touch surfaces. A UV pass filter blocked visible light while allowing UV-C to pass, making it less disturbing to the naked eyes when PPX-UV runs behind glass without curtains. UV is less effective in areas that are out of the direct line of sight; hence separate cycles for each area are recommended with 2 cycles around the patient’s bed. In a typical patient room with living room and separate bathroom, a 5-minute cycle in three different positions is recommended plus 2–3 minutes for positioning for a total of 18 minutes per room (Figure 2). The device emitted ~450 flashes/cycle. The device requires
positioning prior to each 5-minute cycle, so that it is necessary to have an operator in the vicinity. The device was easy to set up and operate per EMS staff operating it.

**Methods**

This comparative study was conducted January-February 2012 in the Central Texas Veterans Health Care System, Temple, TX with approval from its institutional review board. We are a 120-bed acute care hospital. In the facility studied, all patients undergo nasal swab at admission, transfer and discharge; these samples are tested for MRSA by polymerase chain reaction (PCR) (at admission) or culture (transfer/discharge) as a routine process of care according to institutional policy. Patients with MRSA infection either community acquired or hospital acquired are identified by culturing suspicious body site or body fluids. Individuals with MRSA detected by PCR or culture or with prior-year positive PCR/culture are placed on contact isolation during their entire hospitalization. We studied rooms vacated by patients that had a MRSA-positive PCR or culture during the current hospitalization and at least a 2-day stay.

Samples from five high-touch surfaces (bedrail, toilet seat, bathroom handrail, call button, tray table) were collected using Rodac plates, before terminal cleaning of rooms vacated by a patient on isolation for MRSA. For non-flat surfaces such as handrail, contact plates were rolled so that the entire surface was contacted. The rooms were then treated according to one of two protocols: standard manual cleaning or PPX-UV.

In the first group (manual arm; n = 10), rooms were cleaned using the standard procedures. Standard manual cleaning included cleaning visible dirt then soak and wipe cleaning with Dispatch® (The Clorox Company, Oakland, CA) disinfection solution. Dispatch® is a pre-mixed, ready-to-use 1:10 bleach solution with a contact time of 1 minute for killing bacteria. EMS personnel used cotton rags soaked in this pre-mixed solution with one to two applications and passes for all areas and surfaces in a patient room regardless of soiling. On an average, EMS personnel used 3–4 rags per room. These multiuse rags were then laundered for later use in another room. This included all the walls in bathroom and living room up to head height. EMS personnel replaced curtains if present.

In the second group (PPX-UV arm; n = 10), the room was pre-cleaned using same process described in the manual arm using Dispatch® except the focus was to clean only the visibly soiled surfaces instead of every surface in the room to achieve an aesthetic clean vs the thorough cleansing of the manual arm thus saving valuable turnaround time. Then the PPX-UV device was deployed according to manufacturer’s protocol. We then collected our post-cleaning samples ensuring that Dispatch® had completely dried of the sampling surface. Finally, the PPX-UV rooms were cleaned manually per standard protocol (similar to manual arm) to meet requirements for the healthcare facility.

Post-cleaning samples were taken from surface locations immediately adjacent to the pre-cleaning sample locations. In the PPX-UV arm the sampling took place immediately after completion of the PPX-UV cycles for the room. The Rodac sample plates were transported on icepack-lined shipping containers by overnight courier to Antimicrobial Test Laboratories (ATL), an independently contracted microbiology laboratory in nearby Round Rock, Texas. Available rooms were included if they met study criteria (MRSA-positive patient vacating;
sufficient time for shipping that day); they were randomly assigned to either manual or PPX-UV arm. In order to ensure next-day delivery, no samples were collected after the final shipper’s pick-up time of 7 pm. The microbiologist at ATL was blinded to protocol arm. EMS personnel were aware of the fact that samples were being collected pre- and post-cleaning but were not aware of specific surfaces from which samples were being collected.

**Environmental testing procedure**

TSA supplemented with Lecithin and Tween 80 (neutralizes bleach) and HardyCHROM MRSA Rodac contact plates (Hardy Diagnostics, Santa Maria, CA) were received at ATL approximately 18–24 hours after sampling. All samples were given specific identification numbers prior to incubation. HPC and MRSA contact plates were incubated for 48 ± 4 hours at 30 ± 2°C and 36 ± 1°C, respectively, and individual colonies counted immediately after incubation. Every colony, regardless of color or morphology, was recorded for HPC counts. The target organism MRSA was morphologically identified (deep pink to magenta-colored colonies), and regardless of size, were recorded for MRSA counts per package insert from Hardy Diagnostics. Further MRSA colonies were then subcultured and identified using standard microbiological methods. Contact plates resulting in confluent growth were designated as too numerous to count (TNTC) for reporting purposes. TNTC and any plates with a colony count of 250 or higher for MRSA or HPC were assigned a value of 250 colonies.

**Measures and analysis**

We assessed counts of MRSA and HPC for each of 20 rooms, summing samples taken from the five different surfaces to create total MRSA and total HPC counts, respectively, for pre- and post-cleaning measures (four variables in all). Additional measures were individual surface counts, surface type, microbe type (HPC; MRSA), cleaning time in minutes, and room size in square meters. The independent variable of primary interest was cleaning protocol (manual vs PPX-UV).

Colony counts were described with means, medians and the interquartile range (q1–q3). Colony count reductions were calculated as the percent change from pre-cleaning to post-cleaning. Baseline counts were not equivalent per Wilcoxon Rank Sum test, therefore adjusting for the pre-cleaning counts was appropriate. Post-cleaning colony counts were modeled as a function of baseline count and cleaning protocol. Poisson regression is appropriate for modeling count data where the mean is equal to the variance, however, when the data are over-dispersed as these were with the variance greatly exceeding the mean, Poisson regression will under-estimate the standard errors whereas negative binomial regression produces more accurate estimates [16]. Therefore, we used negative binomial regression to estimate the association of cleaning protocol (manual vs PPX-UV) with final colony count, adjusting for baseline counts. The strength of association between predictor and outcome is reported as a regression coefficient for change in the log of counts when the factor is present, and can be exponentiated as an incident rate ratio with 95% confidence interval (IRR, CI95). The IRR is similar to the more familiar odds ratio where a significant effect is one whose CI95 excludes 1. The IRR is the factor by which the expected colony count is multiplied per 1-unit increase in the predictor.

**Results**

Colony counts in 20 rooms (10 per arm) prior to cleaning varied by cleaning protocol: for HPC, manual (mean = 255, median = 278, q1-q3 132–304) vs PPX-UV (mean = 449, median = 365, q1-q3 332–530), and for MRSA, manual (mean = 127; median = 28.5; q1-q3 8–143) vs PPX-UV (mean = 108; median = 123; q1-q3 14–183). These baseline plate counts were not equivalent and were not normally distributed. After cleaning, the counts averaged 60 colonies (76% reduction; manual) vs 8 colonies (98% reduction; PPX-UV) for HPC, and 11 colonies (91% reduction; manual) vs 1 colony (99% reduction) for MRSA. The HPC count was significantly greater for the manual cleaning arm relative to the PPX-UV arm, adjusting for baseline total HPC counts in the rooms (IRR = 12.9, CI95 3.5-47.8, p < .01), meaning the expected count was multiplied by a factor of 13 when the independent variable increased by one unit from 0 (machine) to 1 (manual). Similarly, the MRSA count was significantly higher in the manual cleaning arm relative to the PPX-UV arm (IRR = 7.2, CI95 1.3-41.4, p < .03). See Tables 1, 2 and 3. The majority of the difference in post-cleaning colonies was due to high residual counts on the toilet seats in the manual arm. The number of MRSA-positive sites per room after manual cleaning was 0 (4 rooms), 1 (4 rooms), or 2 (2 rooms), and the number of MRSA-positive sites per room after PX-UV cleaning was 0 (7 rooms), 1 (2 rooms), or 2 (1 room). The average number of minutes spent cleaning a room was 49 minutes including device time (SD = 13) for PPX-UV and 63 minutes (SD = 29) for manual cleaning (t-statistic = 1.5; df = 12.1; p = .17, n.s.). The average size of a patient room (living & bathroom) in the manual arm was 23 m² and in the PPX-UV arm was 25 m².

**Discussion**

Our study showed that a “no-touch” semi-automated system, the PPX-UV, was effective in substantially
reducing the heterotrophic bacterial and MRSA burden on high-touch surfaces in rooms vacated by MRSA-positive patients. PPX-UV disinfection may add to the armamentarium against HAI’s without risking the adaptive genetic resistance incurred by pharmaceutical weapons. Implementation including training EMS personnel to operate the device was minimal, and time spent cleaning was not increased. Because there were separate cycles for bathroom and living room, the surface reduction in aerobic colony counts may be better than with other UV systems; a head-to-head comparison of UV area disinfection devices may be warranted [12,13].

Consistency in patient room-cleaning is needed. High residual colony counts were observed on the toilet seats post-cleaning in the manual arm. This may be due to human inconsistency or memory failure regarding which parts of the room have been cleaned, a common problem with repetitive tasks. A highly structured approach that involves educational, procedural, and administrative interventions with repeated performance feedback to EMS by monitoring the thoroughness of cleaning with either adenosine 5’-triphosphate (ATP) assays or fluorescent dyes has been shown to be successful in reduction of microbial contaminants in patient rooms [17,18]. Other intervention programs such as monitoring room cleanliness using checklists may also result in significant improvement in cleaning practices [19]. Although such interventions improve cleaning, in the post-intervention period the increase is no more than 85% [20], and the effects may decrease post-intervention unless ongoing feedback to environmental services staff is sustained [9]. Thus empowering EMS with a “no touch” semi-automated system such as PPX-UV to substantially reduce the microbial burden on high-touch surfaces, combined with education and feedback, may help us achieve the desired effect of thorough disinfection for every vacated patient room. Training on the device was simple; EMS personnel commented they could easily incorporate this system into their routine cleaning practices. The usual run time of PPX-UV was 15 minutes and required 2–3 minutes of additional setup time. Hence the authors believe PPX-UV disinfection could be integrated into routine hospital cleaning operations without disruption of patient flow or undue burden on EMS staff.

Our study adds to the existing debate in literature about one long cycle vs several shorter cycles for UV disinfection and about a UV device’s effect on aerobic surface colony count reduction. Since separate cycles are needed for bathroom and two positions for living room, the surface reduction in aerobic colony counts was similar to studies of other UV systems that had separate

### Table 1 Methicillin-resistant *Staphylococcus aureus* and bacterial heterotrophic plate counts before and after disinfection per room for five high-touch surfaces total

<table>
<thead>
<tr>
<th>Colony count measures of central tendency and variability by room mean; median (IQR)</th>
<th>Before</th>
<th>After</th>
<th>Reduction</th>
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<tbody>
<tr>
<td><strong>HPC</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Manual arm</td>
<td>255.0; 278.0 (132-304)</td>
<td>60.4; 31.0 (15-70)</td>
<td>76.3%</td>
</tr>
<tr>
<td>PPX-UV arm</td>
<td>449.0; 364.5 (332-530)</td>
<td>8.4; 4.0 (1-10)</td>
<td>98.1%</td>
</tr>
<tr>
<td><strong>MRSA</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Manual arm</td>
<td>127.3; 28.5 (8-143)</td>
<td>11.3; 1.0 (0-4)</td>
<td>91.1%</td>
</tr>
<tr>
<td>PPX-UV arm</td>
<td>108.2; 123.0 (14-183)</td>
<td>0.7; 0.0 (0-1)</td>
<td>99.4%</td>
</tr>
</tbody>
</table>

HPC: Bacterial heterotrophic plate counts. 
MRSA: Methicillin-resistant *Staphylococcus aureus*. 
PPX-UV: Portable pulsed xenon ultraviolet.
Table 3 Total positive plates & colony counts per site by bacterial heterotrophic colony counts and methicillin-resistant Staphylococcus aureus before and after manual and UV light disinfection for 5 high touch surfaces

<table>
<thead>
<tr>
<th>Site</th>
<th>Manual HPC positive plates (colony count)</th>
<th>Manual MRSA positive plates (colony count)</th>
<th>PPX-UV HPC positive plates (colony count)</th>
<th>PPX-UV MRSA positive plates (colony count)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Before After</td>
<td>Before After</td>
<td>Before After</td>
<td>Before After</td>
</tr>
<tr>
<td>Bed rail</td>
<td>10/10 (774) 10/10 (30) 10/10 (1079) 0/10 (0)</td>
<td>8/10 (308) 0/10 (0) 8/10 (188) 0/10 (0)</td>
<td>10/10 (1079) 0/10 (0) 8/10 (188) 0/10 (0)</td>
<td>9/10 (89) 1/10 (1) 8/10 (286) 1/10 (1)</td>
</tr>
<tr>
<td>Call button</td>
<td>10/10 (494) 6/10 (64) 10/10 (1121) 3/10 (54)</td>
<td>9/10 (48) 1/10 (1) 5/10 (10) 1/10 (1)</td>
<td>10/10 (1121) 3/10 (54) 9/10 (48) 1/10 (1)</td>
<td>6/10 (64) 1/10 (1) 5/10 (10) 1/10 (1)</td>
</tr>
<tr>
<td>Tray table</td>
<td>10/10 (311) 8/10 (21) 10/10 (293) 1/10 (4)</td>
<td>9/10 (48) 1/10 (1) 5/10 (10) 1/10 (1)</td>
<td>10/10 (293) 1/10 (4) 9/10 (48) 1/10 (1)</td>
<td>8/10 (269) 3/10 (86) 9/10 (265) 2/10 (5)</td>
</tr>
<tr>
<td>Bathroom handrail</td>
<td>10/10 (392) 10/10 (91) 10/10 (988) 5/10 (20)</td>
<td>9/10 (559) 3/10 (25) 8/10 (333) 0/10 (0)</td>
<td>10/10 (988) 5/10 (20) 9/10 (559) 3/10 (25)</td>
<td>8/10 (269) 3/10 (86) 9/10 (265) 2/10 (5)</td>
</tr>
<tr>
<td>Toilet seat</td>
<td>10/10 (579) 7/10 (398) 10/10 (1009) 2/10 (6)</td>
<td>1/10 (1) 8/10 (269) 3/10 (86) 9/10 (265)</td>
<td>10/10 (1009) 2/10 (6) 1/10 (1) 8/10 (269)</td>
<td>1/10 (1) 8/10 (269) 3/10 (86) 9/10 (265)</td>
</tr>
<tr>
<td>Total</td>
<td>50/50 (2550) 41/50 (604) 50/50 (4490) 11/50 (84)</td>
<td>43/50 (1273) 8/49 (113) 38/50 (1082) 4/50 (7)</td>
<td>50/50 (2550) 41/50 (604) 50/50 (4490) 11/50 (84)</td>
<td>43/50 (1273) 8/49 (113) 38/50 (1082) 4/50 (7)</td>
</tr>
</tbody>
</table>

HPC: Bacterial heterotrophic plate counts.
MRSA: Methicillin-resistant Staphylococcus aureus.
PPX-UV: Portable pulsed xenon ultraviolet.

bathroom cycles and perhaps better surface reduction as compared to studies with no separate bathroom cycles [11–13]. In the PPX-UV arm, the focus was to get the rooms aesthetically clean by manually wiping all grossly soiled surfaces. We believed that our efforts to focus on the aesthetic cleaning, thus allowing for a truncated pre-cleaning routine is consistent with new published literature. Anderson et al. showed that despite lack of pre-cleaning there was statistically significant reduction in organisms such as VRE and C.diff spores [21]. Zhang et al. also showed that the organic material from the hospital rooms only modestly affected UV killing of spores [22]. The above research findings could explain why PPX-UV arm had lower counts inspite of a truncated pre-cleaning routine. The manufacturer recommended the same cycle times for patient rooms with c. diff spores based on preliminary lab data, and studies are underway at another site to examine the efficacy on c. diff spores in a hospital setting, however, future independent research should directly assess sporicidal capacity of the PPX-UV. Federally funded multi-site comparative study with multiple microbial targets is currently underway. Future research should also assess patient outcomes and cost-effectiveness for major and emergent infectious agents in healthcare systems with and without systematic PPX-UV cleaning.

Our study has several limitations: it was not designed to assess impact on the actual transmission of healthcare-acquired infections. The number of surfaces and rooms sampled was small but similar in size to previously published studies [11,12]. The protocol did not evaluate the incremental impact of UVC treatment following routine cleaning, a process to be evaluated in our next study. The delay to culture introduced by the overnight transport process may have influenced culture viability, however, both manual and PPX-UV samples experienced the same transport periods thus reducing likelihood of bias from this source of variability. EMS personnel were not blinded to the study nor to the protocol to be used in each room. Supervisors commented that they were taking longer than usual to clean the rooms, suggesting increased vigilance; this would potentially bias our results toward the null. Better differential effects might be achieved in a real-world implementation where lapses in EMS attentiveness may occur unpredictably. The rather high post-cleaning MRSA counts in the manual cleaning arm may point to another area of research, comparing the quality of manual cleaning protocols across hospital systems. It is possible that higher bacterial counts in the manual arm may be due to lack of actual manual cleaning process rather than the lack of efficacy of the manual cleaning process. While it is possible that ours is the only facility in the VA system whose cleaning crew has inconsistency in cleaning thoroughness, we suspect it is more a part of the human condition. Two multisite trials that we know of are currently in progress and should provide larger scale results on PPX-UV effectiveness.

Conclusions
In conclusion, PPX-UV technology appears to be superior to manual cleaning alone for MRSA and HPC. We believe incorporating 15 minutes of PPX-UV exposure time to current hospital room cleaning practice can improve the overall cleanliness of patient rooms with respect to selected micro-organisms by a factor of 7–12 in a sustainable manner. Outcome studies are being conducted to assess the economic and clinical impact of this technology.

Competing interests
This study’s laboratory activity including use of the PPX-UV machine was supported by a grant from Xenex Healthcare Services, LLC. No author has identified a competing interest regarding the study beyond working for the institution studied (Department of Veterans Affairs, Veterans Health Administration).
Authors' contributions
All authors made a significant contribution to the project. CJ and RQ developed the methodology, protocol, performed data collection and manuscript preparation. TH and JW carried out the microbiology and contributed to the manuscript. JZ and LC participated in statistical analysis and contributed to the manuscript. All authors read and approved the final manuscript.

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Funding
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Brief report

Can pulsed xenon ultraviolet light systems disinfect aerobic bacteria in the absence of manual disinfection?

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Key Words:
No-touch disinfection
Enhanced manual cleaning
Aerobic bacteria colony count
Hospital acquired infections

Aerobic bacterial colony (ABC) counts on hospital high-touch surfaces indicate the level of microbiologic contamination.\textsuperscript{1} ABC counts have been used in studies to assess the effectiveness of mercury-based ultraviolet (Hg-UV) and pulsed xenon-based ultraviolet (PX-UV) no-touch disinfection devices (NTD).\textsuperscript{2,4} Although a room could be disinfected manually without using NTD, the reverse is not accepted practice.\textsuperscript{2,5} But there may be occasions where surfaces are not thoroughly disinfected due to human error or significant contamination.\textsuperscript{6} There is evidence to suggest the effectiveness of Hg-UV disinfection on ABC counts in the absence of any manual cleaning, but, such data is lacking for PX-UV disinfection devices.\textsuperscript{2,4} Hence, we devised a study to evaluate the effectiveness of PX-UV disinfection on ABC counts in the absence of any manual disinfection.

MATERIALS AND METHODS

To determine if the PX-UV disinfection system can effectively reduce ABC without prior manual disinfection, a prospective pre-post study design was developed. The study site was a single Veterans Affairs facility located in Temple, Texas. A convenience sample of 38 recently vacated rooms \((n = 38)\) that had not yet undergone any manual disinfection and had been occupied for a minimum of 48 hours were identified and before and after PX-UV surface samples were collected. The description of the device and the methodology used for disinfection was similar to those described in Jinadatha et al\textsuperscript{3} except there was no manual disinfection before PX-UV use. Five high-touch surfaces within each room were sampled before and after PX-UV disinfection. The surfaces included 3 in the patient room (ie, call button, bedrail, and tray table) and 2 in the bathroom (ie, handrail and toilet). Therefore, a total of 190 samples before and after PX-UV disinfection were obtained across 38 rooms.
Huang et al.8 showed a 40% increased odds of transmission for samples taken before disinfection. Then post-PX-UV samples were collected in areas adjacent to the samples were taken the PX-UV was used to disinfect the room and non-sampled by press plate technique. Roll plate method was used for such as food particles or spilt condiments, the area adjacent was used for sampling of surfaces. If gross visible soiling was observed, Rodac contact plates (Hardy Diagnostics, Santa Maria, Calif) were implemented by PX-UV disinfection in vacated hospital rooms.5 But we were not able to delineate if PX-UV was effective on surfaces we were not able to delineate if PX-UV was effective on surfaces where Environmental Management Services personnel did not apply a chemical disinfectant, which is part of standard cleaning protocol. It is highly unlikely that the UV light devices are going to be used alone without manual precleaning, for aesthetic reasons. Although our study is not intended to advocate abandoning manual disinfection practices altogether, it provides insight into what happens if a surface is missed by Environmental Management Services personnel during manual disinfection when PX-UV is subsequently deployed. Our study had several limitations, including no evaluation of organism-specific reduction. This study was conducted in a Veterans Affairs hospital setting and may not be generalizable to community hospitals. Although the sample size was small, it represents a larger cohort than other previously reported studies.15

RESULTS

The overall mean ABC count across all 190 samples before PX-Uv disinfection was 73.6 (95% CI, 63.8-83.4) (Table 1). The surface with greatest ABC count was the call button, with a mean of 88.5 (95% CI, 66.7-110.3), followed by the bedrail, with a mean 84.0 (95% CI, 61.6-106.4). The tray table had the lowest mean ABC count before PX-Uv disinfection, with 54.5 (95% CI, 34.5-74.5). After disinfection, the call button had the greatest mean ABC count reduction of 72.4 (median reduction of 66.0; P < .01). All high-touch surfaces experienced a significant reduction in ABC count. Overall, before PX-Uv disinfection, 187 (98.4%) of the surfaces were contaminated with aerobic bacteria; this was reduced to 169 (88.9%) surfaces after disinfection, leading to 18 (9.6%) contaminated surfaces now becoming free of aerobic bacteria after PX-Uv disinfection. Levels of ABC were reduced from 74 ± 10 to no more than 20 ± 3 colonies overall, with the highest residual counts on bathroom surfaces. When the results from Table 1 were compared with ABC count reduction after standard manual disinfection without use of PX-UV disinfection, the results were similar (data not shown).

DISCUSSION

Surface contamination has been shown to play a significant role in the acquisition of hospital-acquired infections.7,8 In fact, Huang et al.8 showed a 40% increased odds of transmission for methicillin-resistant *Staphylococcus aureus* and vancomycin-resistant enterococci if the room’s previous occupant was positive for either antibiotic-resistant bacteria. The current standard for disinfection in most hospitals is manual cleaning by Environmental Management Services staff with disinfectants.7 These methods are inconsistent and often inadequate in decreasing environmental bioburden.5,10 Newer NTD technologies have the potential to supplement manual disinfection to provide enhanced disinfection.12 Anderson et al.12 showed that HG-Uv is effective at decreasing the ABC counts in hospital settings even in the absence of manual disinfection. However, until now research has been lacking for PX-Uv disinfection systems. Our study results indicate that PX-UV disinfection reduces aerobic bacteria in the absence of manual disinfection. Our results were similar to the reduction of ABC counts seen in other studies that used a mercury-based no-touch UV disinfection device.14 In our previous study, we evaluated a properly truncated aesthetic cleaning protocol supplemented by PX-UV disinfection in vacated hospital rooms.15 But we were not able to delineate if PX-Uv was effective on surfaces where Environmental Management Services personnel did not apply a chemical disinfectant, which is part of standard cleaning protocol. It is highly unlikely that the UV light devices are going to be used alone without manual precleaning, for aesthetic reasons. Although our study is not intended to advocate abandoning manual disinfection practices altogether, it provides insight into what happens if a surface is missed by Environmental Management Services personnel during manual disinfection when PX-Uv is subsequently deployed. Our study had several limitations, including no evaluation of organism-specific reduction. This study was conducted in a Veterans Affairs hospital setting and may not be generalizable to community hospitals. Although the sample size was small, it represents a larger cohort than other previously reported studies.15

CONCLUSIONS

Our study suggests that PX-Uv effectively reduces ABC counts in the absence of manual disinfection. These data are important for hospitals that plan to adapt this technology as adjunct to routine manual disinfection and alleviate any fears that adopting this technology may actually harm patients because Environmental Management Services personnel may miss surfaces.

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Infection Prevention and Control Department; Allen Lassiter and the Environmental Management Services team; and the nursing service personnel for their help in coordinating study activities.

References

Evaluation of a pulsed-xenon ultraviolet room disinfection device for impact on contamination levels of methicillin-resistant Staphylococcus aureus


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Abstract

Background

Healthcare-acquired infections with methicillin-resistant *Staphylococcus aureus* (MRSA) are a significant cause of increased mortality, morbidity and additional health care costs in United States. Surface decontamination technologies that utilize pulsed xenon ultraviolet light (PPX-UV) may be effective at reducing microbial burden. The purpose of this study was to compare standard manual room-cleaning to PPX-UV disinfection technology for MRSA and bacterial heterotrophic plate counts (HPC) on high-touch surfaces in patient rooms.

Methods

Rooms vacated by patients that had a MRSA-positive polymerase chain reaction or culture during the current hospitalization and at least a 2-day stay were studied. 20 rooms were then treated according to one of two protocols: standard manual cleaning or PPX-UV. This study evaluated the reduction of MRSA and HPC taken from five high-touch surfaces in rooms
vacated by MRSA-positive patients, as a function of cleaning by standard manual methods vs a PPX-UV area disinfection device.

Results

Colony counts in 20 rooms (10 per arm) prior to cleaning varied by cleaning protocol: for HPC, manual (mean = 255, median = 278, q1-q3 132–304) vs PPX-UV (mean = 449, median = 365, q1-q3 332–530), and for MRSA, manual (mean = 127; median = 28.5; q1-q3 8–143) vs PPX-UV (mean = 108; median = 123; q1-q3 14–183). PPX-UV was superior to manual cleaning for MRSA (adjusted incident rate ratio [IRR] = 7; 95% CI <1-41) and for HPC (IRR = 13; 95% CI 4–48).

Conclusion

PPX-UV technology appears to be superior to manual cleaning alone for MRSA and HPC. Incorporating 15 minutes of PPX-UV exposure time to current hospital room cleaning practice can improve the overall cleanliness of patient rooms with respect to selected microorganisms.

Keywords

MRSA, Methicillin-resistant Staphylococcus aureus, No touch disinfection, Pulsed Xenon Ultraviolet disinfection device, nosocomial infections

Background

Healthcare-acquired infection (HAI) with methicillin-resistant Staphylococcus aureus (MRSA) is a significant cause of mortality and morbidity in the United States accounting for up to $9.7 billion annually in additional health care costs, and €44.0 million annually in Europe [1,2]. In the Americas, Europe, and parts of Africa and Asia, MRSA is the predominant multi-drug resistant microbe, making it a global concern of escalating importance in terms of cost and patient safety [3]. Combating MRSA with new pharmaceutical agents offers only short-term solutions; unconventional approaches may comprise a more effective solution to drug-resistant infectious microbes [4].

Patients admitted to rooms vacated by MRSA-positive patients have higher relative risk of acquiring MRSA [5,6]. In a 2009 review of environmental cleaning studies, Dancer concluded that high-touch surfaces present one of the biggest risks of MRSA acquisition for patients, providing a source of direct infection to patients and of indirect infection via healthcare workers [7]. Decontaminating high-touch surfaces could prevent HAI [8]. Manual cleaning with approved disinfectants is the current standard of disinfection in most countries including the United States, and this requires supervision with constant reinforcement and education of environmental management service (EMS) staff to maintain effectiveness [9].

Surface decontamination technologies that utilize ultraviolet light or hydrogen peroxide may be effective at reducing microbial burden, possibly with greater consistency than is achieved with manual methods [10-13]. Portable pulsed xenon ultraviolet (PPX-UV) technology uses high-intensity broad-spectrum UV irradiation in the 200–320 nm range. UV breaks the
molecular bonds in DNA, thereby destroying the organism and spores in laboratory settings [12,14]. Spores from Clostridium difficile (c.diff) are killed by 185–230 nm UV irradiation, overlapping the range of the PPX-UV [15].

The efficacy of PPX-UV in hospitals in comparison to manual cleaning has not been demonstrated. The purpose of this study was to compare standard manual room-cleaning to PPX-UV disinfection technology for MRSA and bacterial heterotrophic plate counts (HPC) on high-touch surfaces in patient rooms.

**PPX-UV device**

We used a portable PPX-UV device (Xenex Healthcare Services, San Antonio, TX) measuring 30 L x 20 W x 38H inches (Figure 1). The device is used in empty patient rooms after discharge as prolonged exposure to UV can skin and eye irritation. The device used in this study housed a bulb twice as intense as in the device described by Stibich and colleagues [10], and it had new features such as a data logger, reflector, and UV pass filter. The data log recorded room number, user ID, time, date, number of pulses, amount of energy emitted and any error codes. The reflector was mounted on a column housing the xenon gas bulb emitting the pulsed UV rays. While column moved up and down during a 5-minute cycle, the reflector optimized the UV rays downward to high-touch surfaces. A UV pass filter blocked visible light while allowing UV-C to pass, making it less disturbing to the naked eyes when PPX-UV runs behind glass without curtains. UV is less effective in areas that are out of the direct line of sight; hence separate cycles for each area are recommended with 2 cycles around the patient's bed. In a typical patient room with living room and separate bathroom, a 5-minute cycle in three different positions is recommended plus 2–3 minutes for positioning for a total of 18 minutes per room (Figure 2). The device emitted ~450 flashes/cycle. The device requires positioning prior to each 5-minute cycle, so that it is necessary to have an operator in the vicinity. The device was easy to set up and operate per EMS staff operating it.

**Figure 1 Photograph of the PPX-UV device.**

**Figure 2 Schematic of two patient rooms showing positioning of PPX-UV unit.**

**Methods**

This comparative study was conducted January-February 2012 in the Central Texas Veterans Health Care System, Temple, TX with approval from its institutional review board. We are a 120-bed acute care hospital. In the facility studied, all patients undergo nasal swab at admission, transfer and discharge; these samples are tested for MRSA by polymerase chain reaction (PCR) (at admission) or culture (transfer/discharge) as a routine process of care according to institutional policy. Patients with MRSA infection either community acquired or hospital acquired are identified by culturing suspicious body site or body fluids. Individuals with MRSA detected by PCR or culture or with prior-year positive PCR/culture are placed on contact isolation during their entire hospitalization. We studied rooms vacated by patients that had a MRSA-positive PCR or culture during the current hospitalization and at least a 2-day stay.

Samples from five high-touch surfaces (bedrail, toilet seat, bathroom handrail, call button, tray table) were collected using Rodac plates, before terminal cleaning of rooms vacated by a
patient on isolation for MRSA. For non-flat surfaces such as handrail, contact plates were rolled so that the entire surface was contacted. The rooms were then treated according to one of two protocols: standard manual cleaning or PPX-UV.

In the first group (manual arm; n = 10), rooms were cleaned using the standard procedures. Standard manual cleaning included cleaning visible dirt then soak and-wipe cleaning with Dispatch® (The Clorox Company, Oakland, CA) disinfection solution. Dispatch® is a pre-mixed, ready-to-use 1:10 bleach solution with a contact time of 1 minute for killing bacteria. EMS personnel used cotton rags soaked in this pre-mixed solution with one to two applications and passes for all areas and surfaces in a patient room regardless of soiling. On an average, EMS personnel used 3–4 rags per room. These multiuse rags were then laundered for later use in another room. This included all the walls in a bathroom and living room up to head height. EMS personnel replaced curtains if present.

In the second group (PPX-UV arm; n = 10), the room was pre-cleaned using same process described in the manual arm using Dispatch® except the focus was to clean only the visibly soiled surfaces instead of every surface in the room to achieve an aesthetic clean vs the thorough cleansing of the manual arm thus saving valuable turn-around time. Then the PPX-UV device was deployed according to manufacturer's protocol. We then collected our post-cleaning samples ensuring that Dispatch® had completely dried of the sampling surface. Finally, the PPX-UV rooms were cleaned manually per standard protocol (similar to manual arm) to meet requirements for the healthcare facility.

Post-cleaning samples were taken from surface locations immediately adjacent to the pre-cleaning sample locations. In the PPX-UV arm the sampling took place immediately after completion of the PPX-UV cycles for the room. The Rodac sample plates were transported on icepack-lined shipping containers by overnight courier to Antimicrobial Test Laboratories (ATL), an independently contracted microbiology laboratory in nearby Round Rock, Texas. Available rooms were included if they met study criteria (MRSA-positive patient vacating; sufficient time for shipping that day; they were randomly assigned to either manual or PPX-UV arm. In order to ensure next-day delivery, no samples were collected after the final shipper’s pick-up time of 7 pm. The microbiologist at ATL was blinded to protocol arm. EMS personnel were aware of the fact that samples were being collected pre- and post-cleaning but were not aware of specific surfaces from which samples were being collected.

Environmental testing procedure

TSA supplemented with Lecithin and Tween 80 (neutralizes bleach) and HardyCHROM MRSA Rodac contact plates (Hardy Diagnostics, Santa Maria, CA) were received at ATL approximately 18–24 hours after sampling. All samples were given specific identification numbers prior to incubation. HPC and MRSA contact plates were incubated for 48 ± 4 hours at 30 ± 2°C and 36 ± 1°C, respectively, and individual colonies counted immediately after incubation. Every colony, regardless of color or morphology, was recorded for HPC counts. The target organism MRSA was morphologically identified (deep pink to magenta-colored colonies), and regardless of size, were recorded for MRSA counts per package insert from Hardy Diagnostics. Further MRSA colonies were then subcultured and identified using standard microbiological methods. Contact plates resulting in confluent growth were designated as too numerous to count (TNTC) for reporting purposes. TNTC and any plates with a colony count of 250 or higher for MRSA or HPC were assigned a value of 250 colonies.
Measures and analysis

We assessed counts of MRSA and HPC for each of 20 rooms, summing samples taken from the five different surfaces to create total MRSA and total HPC counts, respectively, for pre-and post-cleaning measures (four variables in all). Additional measures were individual surface counts, surface type, microbe type (HPC; MRSA), cleaning time in minutes, and room size in square meters. The independent variable of primary interest was cleaning protocol (manual vs PPX-UV). Colony counts were described with means, medians and the interquartile range (q1-q3). Colony count reductions were calculated as the percent change from pre-cleaning to post-cleaning. Baseline counts were not equivalent per Wilcoxon Rank Sum test, therefore adjusting for the pre-cleaning counts was appropriate. Post-cleaning colony counts were modeled as a function of baseline count and cleaning protocol. Poisson regression is appropriate for modeling count data where the mean is equal to the variance, however, when the data are over-dispersed as these were with the variance greatly exceeding the mean, Poisson regression will under-estimate the standard errors whereas negative binomial regression produces more accurate estimates [16]. Therefore, we used negative binomial regression to estimate the association of cleaning protocol (manual vs PPX-UV) with final colony count, adjusting for baseline counts. The strength of association between predictor and outcome is reported as a regression coefficient for change in the log of counts when the factor is present, and can be exponentiated as an incident rate ratio with 95% confidence interval (IRR, CI95). The IRR is similar to the more familiar odds ratio where a significant effect is one whose CI95 excludes 1. The IRR is the factor by which the expected colony count is multiplied per 1-unit increase in the predictor. For the cleaning protocol, the predictor was either 0 (PPX-UV) or 1 (manual cleaning).

Results

Colony counts in 20 rooms (10 per arm) prior to cleaning varied by cleaning protocol: for HPC, manual (mean = 255, median = 278, q1-q3 132–304) vs PPX-UV (mean = 449, median = 365, q1-q3 332–530), and for MRSA, manual (mean = 127; median = 28.5; q1-q3 8–143) vs PPX-UV (mean = 108; median = 123; q1-q3 14–183). These baseline plate counts were not equivalent and were not normally distributed. After cleaning, the counts averaged 60 colonies (76% reduction; manual) vs 8 colonies (98% reduction; PPX-UV) for HPC, and 11 colonies (91% reduction; manual) vs 1 colony (99% reduction) for MRSA. The HPC count was significantly greater for the manual cleaning arm relative to the PPX-UV arm, adjusting for baseline total HPC counts in the rooms (IRR = 12.9, CI95 3.5-47.8, p < .01), meaning the expected count was multiplied by a factor of 13 when the independent variable increased by one unit from 0 (machine) to 1 (manual). Similarly, the MRSA count was significantly higher in the manual cleaning arm relative to the PPX-UV arm (IRR = 7.2, CI95 1.3-41.4, p < .03). See Tables 1, 2, 3. The majority of the difference in post-cleaning colonies was due to high residual counts on the toilet seats in the manual arm. The number of MRSA-positive sites per room after manual cleaning was 0 (4 rooms), 1 (4 rooms), or 2 (2 rooms), and the number of MRSA-positive sites per room after PX-UV cleaning was 0 (7 rooms), 1 (2 rooms), or 2 (1 room). The average number of minutes spent cleaning a room was 49 minutes including device time (SD = 13) for PPX-UV and 63 minutes (SD = 29) for manual cleaning (t-statistic = 1.5; df = 12.1; p = .17, n.s.). The average size of a patient room (living & bathroom) in the manual arm was 23 m$^2$ and in the PPX-UV arm was 25 m$^2$.
Table 1 Methicillin-resistant *Staphylococcus aureus* and bacterial heterotrophic plate counts before and after disinfection per room for five high-touch surfaces total

| Colony Count Measures of Central Tendency and Variability by Room Mean; Median (IQR) |
|----------------------------------|--------|--------|--------|
|                                   | Before            | After             | Reduction |
| HPC                               |                   |                   |          |
| Manual arm                        | 255.0; 278.0 (132-304) | 60.4; 31.0 (15-70) | 76.3%    |
| PPX-UV arm                        | 449.0; 364.5 (332-530) | 8.4; 4.0 (1-10)   | 98.1%    |
| MRSA                              |                   |                   |          |
| Manual arm                        | 127.3; 28.5 (8-143) | 11.3; 1.0 (0-4)   | 91.1%    |
| PPX-UV arm                        | 108.2; 123.0 (14-183) | 0.7; 0.0 (0-1)    | 99.4%    |

HPC: Bacterial heterotrophic plate counts.
MRSA: Methicillin-resistant *Staphylococcus aureus*.
PPX-UV: Portable pulsed xenon ultraviolet.
### Table 2: Estimated effect of cleaning protocol on colony counts: manual cleaning vs portable pulsed ultraviolet machine cleaning (N = 20 Rooms)

<table>
<thead>
<tr>
<th>Type of Colonies</th>
<th>Regression Coefficient (beta)</th>
<th>95% CI for beta</th>
<th>Incident Rate Ratio (exp(beta))</th>
<th>95% CI for IRR</th>
<th>Chi-square statistic</th>
<th>Pr</th>
</tr>
</thead>
<tbody>
<tr>
<td>MRSA Baseline count</td>
<td>0.004</td>
<td>&lt;0.0-0.001</td>
<td>--</td>
<td>--</td>
<td>3.24</td>
<td>0.07</td>
</tr>
<tr>
<td>Manual cleaning</td>
<td>2.0</td>
<td>0.2-3.7</td>
<td>7.2</td>
<td>1.3-41.4</td>
<td>4.91</td>
<td>0.03</td>
</tr>
<tr>
<td>HPC Baseline count</td>
<td>0.002</td>
<td>&lt;0.0-0.01</td>
<td>--</td>
<td>--</td>
<td>1.49</td>
<td>0.22</td>
</tr>
<tr>
<td>Manual cleaning</td>
<td>2.6</td>
<td>1.3-3.8</td>
<td>12.9</td>
<td>3.5-47.8</td>
<td>14.7</td>
<td>&lt;.01</td>
</tr>
</tbody>
</table>

### Table 3: Total positive plates & colony counts per site by bacterial heterotrophic colony counts and Methicillin-resistant *Staphylococcus aureus* before and after manual and UV light disinfection for 5 high touch surfaces

<table>
<thead>
<tr>
<th>Site</th>
<th>HPC Positive plates (Colony Count)</th>
<th>MRSA Positive plates (Colony Count)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Manual Before</td>
<td>After</td>
</tr>
<tr>
<td>Bed rail</td>
<td>10/10 (774)</td>
<td>10/10 (30)</td>
</tr>
<tr>
<td>Call button</td>
<td>10/10 (494)</td>
<td>6/10 (64)</td>
</tr>
<tr>
<td>Tray table</td>
<td>10/10 (311)</td>
<td>8/10 (21)</td>
</tr>
<tr>
<td>Bathroom handrail</td>
<td>10/10 (392)</td>
<td>10/10 (91)</td>
</tr>
<tr>
<td>Toilet seat</td>
<td>10/10 (579)</td>
<td>7/10 (398)</td>
</tr>
<tr>
<td>Total</td>
<td>50/50 (2550)</td>
<td>41/50 (604)</td>
</tr>
</tbody>
</table>

HPC: Bacterial heterotrophic plate counts.

MRSA: Methicillin-resistant *Staphylococcus aureus*.

PPX-UV: Portable pulsed xenon Ultraviolet.
Discussion

Our study showed that a “no-touch” semi-automated system, the PPX-UV, was effective in substantially reducing the heterotrophic bacterial and MRSA burden on high-touch surfaces in rooms vacated by MRSA-positive patients. PPX-UV disinfection may add to the armamentarium against HAI’s without risking the adaptive genetic resistance incurred by pharmaceutical weapons. Implementation including training EMS personnel to operate the device was minimal, and time spent cleaning was not increased. Because there were separate cycles for bathroom and living room, the surface reduction in aerobic colony counts may be better than with other UV systems; a head-to-head comparison of UV area disinfection devices may be warranted [12,13].

Consistency in patient room-cleaning is needed. High residual colony counts were observed on the toilet seats post-cleaning in the manual arm. This may be due to human inconsistency or memory failure regarding which parts of the room have been cleaned, a common problem with repetitive tasks. A highly structured approach that involves educational, procedural, and administrative interventions with repeated performance feedback to EMS by monitoring the thoroughness of cleaning with either adenosine 5’-triphosphate (ATP) assays or fluorescent dyes has been shown to be successful in reduction of microbial contaminants in patient rooms [17,18]. Other intervention programs such as monitoring room cleanliness using checklists may also result in significant improvement in cleaning practices [19]. Although such interventions improve cleaning, in the post-intervention period the increase is no more than 85% [20], and the effects may decrease post-intervention unless ongoing feedback to environmental services staff is sustained [9]. Thus empowering EMS with a “no touch” semi-automated system such as PPX-UV to substantially reduce the microbial burden on high-touch surfaces, combined with education and feedback, may help us achieve the desired effect of thorough disinfection for every vacated patient room. Training on the device was simple; EMS personnel commented they could easily incorporate this system into their routine cleaning practices. The usual run time of PPX-UV was 15 minutes and required 2–3 minutes of additional setup time. Hence the authors believe PPX-UV disinfection could be integrated into routine hospital cleaning operations without disruption of patient flow or undue burden on EMS staff.

Our study adds to the existing debate in literature about one long cycle vs several shorter cycles for UV disinfection and about a UV device’s effect on aerobic surface colony count reduction. Since separate cycles are needed for bathroom and two positions for living room, the surface reduction in aerobic colony counts was similar to studies of other UV systems that had separate bathroom cycles and perhaps better surface reduction as compared to studies with no separate bathroom cycles [11-13]. In the PPX-UV arm, the focus was to get the rooms aesthetically clean by manually wiping all grossly soiled surfaces. We believed that our efforts to focus on the aesthetic cleaning, thus allowing for a truncated pre-cleaning routine is consistent with new published literature. Anderson et al. showed that despite lack of pre-cleaning there was statistically significant reduction in organisms such as VRE and C.diff spores [21]. Zhang et al. also showed that the organic material from the hospital rooms only modestly affected UV killing of spores [22]. The above research findings could explain why PPX-UV arm had lower counts inspite of a truncated pre-cleaning routine. The manufacturer recommended the same cycle times for patient rooms with c.diff spores based on preliminary lab data, and studies are underway at another site to examine the efficacy on c.diff spores in a hospital setting, however, future independent research should directly assess sporidical capacity of the PPX-UV. Federally funded multi-site comparative study with
multiple microbial targets is currently underway. Future research should also assess patient outcomes and cost-effectiveness for major and emergent infectious agents in healthcare systems with and without systematic PPX-UV cleaning.

Our study has several limitations: it was not designed to assess impact on the actual transmission of healthcare-acquired infections. The number of surfaces and rooms sampled was small but similar in size to previously published studies [11,12]. The protocol did not evaluate the incremental impact of UVC treatment following routine cleaning, a process to be evaluated in our next study. The delay to culture introduced by the overnight transport process may have influenced culture viability, however, both manual and PPX-UV samples experienced the same transport periods thus reducing likelihood of bias from this source of variability. EMS personnel were not blinded to the study nor to the protocol to be used in each room. Supervisors commented that they were taking longer than usual to clean the rooms, suggesting increased vigilance; this would potentially bias our results toward the null. Better differential effects might be achieved in a real-world implementation where lapses in EMS attentiveness may occur unpredictably. The rather high post-cleaning MRSA counts in the manual cleaning arm may point to another area of research, comparing the quality of manual cleaning protocols across hospital systems. It is possible that higher bacterial counts in the manual arm may be due to lack of actual manual cleaning process rather than the lack of efficacy of the manual cleaning process. While it is possible that ours is the only facility in the VA system whose cleaning crew has inconsistency in cleaning thoroughness, we suspect it is more a part of the human condition. Two multisite trials that we know of are currently in progress and should provide larger scale results on PPX-UV effectiveness.

Conclusions

In conclusion, PPX-UV technology appears to be superior to manual cleaning alone for MRSA and HPC. We believe incorporating 15 minutes of PPX-UV exposure time to current hospital room cleaning practice can improve the overall cleanliness of patient rooms with respect to selected micro-organisms by a factor of 7–12 in a sustainable manner. Outcome studies are being conducted to assess the economic and clinical impact of this technology.

Competing interests

This study's laboratory activity including use of the PPX-UV machine was supported by a grant from Xenex Healthcare Services, LLC. No author has identified a competing interest regarding the study beyond working for the institution studied (Department of Veterans Affairs, Veterans Health Administration).

Authors’ contributions

All authors made a significant contribution to the project. CJ and RQ developed the methodology, protocol, performed data collection and manuscript preparation. TH and JW carried out the microbiology and contributed to the manuscript. JZ and LC participated in statistical analysis and contributed to the manuscript. All authors read and approved the final manuscript.
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This study’s laboratory activity including use of the PPX-UV machine was supported by a grant from Xenex Healthcare Services, LLC.

References


Brief report

The effect of portable pulsed xenon ultraviolet light after terminal cleaning on hospital-associated *Clostridium difficile* infection in a community hospital

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Key Words:
* C difficile
* Hospital infection
* Colectomy
* UV light
* Disinfection
* Technology

There is evidence that contamination of patient rooms from previous occupants is associated with hospital-associated *Clostridium difficile* infection (HA-CDI). 1,2 A number of environmental interventions have been introduced to attempt to decrease *C difficile* transmission within hospitals. Although guidelines published by the Society for Healthcare Epidemiology of America (SHEA) 3 for CDI were followed in our hospital, CDI remained a concerning clinical issue. These guidelines include, for *C difficile* rooms, the use of chlorine-based agents for daily and terminal cleaning of rooms where patients with *C difficile* are housed, contact precaution measures for the duration of the hospital stay, and use of soap and water for hand hygiene. We had also implemented enhanced education on improved cleaning techniques and competency evaluations for our environmental services (ES) workers prior to the use of the ultraviolet (UV) light.

Rutala and Weber 4 state that “new technologies hold the promise for improved disinfection of rooms with *C difficile* surface contamination.” Specifically, both Rutala et al. 4 and Nerandzic et al. 5 showed that UV light treatment has the potential to lower environmental *C difficile* contamination levels in patient rooms. Both Boyce et al. 6 and Stibich et al. 7 demonstrated the effectiveness of portable UV light devices on deactivating *C difficile* endospores. To date, however, no one has demonstrated clinical impact on facility-wide HA-CDI with the use of automated environmental decontamination technology. We report a significant decrease in the HA-CDI rate, as well as in the number of both CDI-related deaths and CDI-related colectomies after hospital-wide implementation of portable pulsed xenon UV (PPX-UV).

**METHODS**

Cooley Dickinson Hospital is a 140-bed acute care community hospital in western Massachusetts with mostly single-bed rooms. During January 2011, the use of 2 PPX-UV devices (Xenex Healthcare Services, San Antonio, TX) to disinfect patient rooms was introduced. Rooms and bathrooms were terminally cleaned as usual with a hospital-grade disinfectant product (ph7Q Ultra; Betco Corporation, Toledo, OH) in most rooms and a chlorine-based product (Clorox Clean-up and Clorox Germ Wipes; The Clorox Company, Oakland, CA) in *C difficile* rooms. This was followed by the use of PPX-UV, for three 7-minute exposures (once in the bathroom and then in 2 locations in the main patient room). The overall room turn-over time was extended by approximately 15 minutes over a standard terminal cleaning because cleaning could continue in the main room during PPX-UV treatment of the bathroom.

PPX-UV devices were also used in the operating suites (nights), emergency department (early mornings), and other clinical areas as available. Surveillance for HA-CDI (hospital onset plus community onset) using SHEA definitions 5 continued as per Infection...
Prevention Department routine. No environmental sampling was performed.

Description and cost of the device

The PPX-UV device contains a xenon flash lamp that emits a broad spectrum of light covering the germicidal, or ultraviolet-C (UV-C), spectrum of 200 to 280 nm as well as the visible light spectrum. The device weighs approximately 150 pounds and is approximately 20 inches wide by 30 inches long by 38 inches high. The PPX-UV system produces a pulsed flash at a frequency of 1.5 Hz with an approximate output of 505 J per pulse and a duration of less than 360 μs. The device is operated remotely by ES personnel in the hallway just outside the patient room and includes safety features such as motion sensors, which turn off the device if the door is opened. The operating time for the device for C difficile deactivation was 7 minutes per position. Leasing 2 machines cost less than $5,000 per month.

Baseline infection prevention policies and ES procedures

Throughout the study period, our policy followed SHEA guidelines including use of chlorine-based agents for terminal cleaning of C difficile rooms, use of soap and water for hand hygiene, and contact precautions for the duration of the hospital stay. Patients were put on contact precautions when C difficile infection was suspected but not necessarily proven. Adherence to policy was not measured. No new infection prevention policies or protocols were pursued during the intervention year.

There was no real-time antibiotic stewardship before or during the intervention. However, ciprofloxacin was added to the formulary in early 2010, with a decline in levofloxacin use and total quinolone use. As noted in Table 1, levofloxacin use (adjusted for patient-days) declined 38.6% with a rise in ciprofloxacin use, and total quinolone use declined 14.8% during the year prior to the intervention. During the intervention year, levofloxacin use continued to fall, although more modestly, and total quinolone use fell minimally. No new formulary initiatives were pursued during the intervention year.

In the previous 2 years, ES workers were educated to standardize cleaning practices and were taught about the role of environmental contamination in transmitting infections. In addition, an improved communication system (using beeper messages to alert ES staff when a room needed to be cleaned) was implemented to increase efficiency in room turnover and to inform housekeepers when chlorine-based products were needed.

PPX-UV implementation

The PPX-UV device utilization was prioritized as follows: discharged contact precaution rooms, intensive care unit rooms, and other medical/surgical/labor and delivery rooms (with the goal of using the PPX-UV device in every room after patient discharge), and in operating rooms, emergency department rooms, and on shared medical equipment when possible. No new ES workers were hired to implement this protocol.

Testing for and diagnosing C difficile

In early 2009 in-house testing for C difficile was changed from a toxin A-only enzyme immunoassay card test to the Meridian Immunocardi Toxins A and B (Meridian, Charlotte, NC), with occasional use of a send-out polymerase chain reaction (PCR) test (Real-time PCR using LightCycler and Fluorescent Resonance Energy Transfer; Mayo, Rochester, MN). In 2011 results from (more frequently used) PCR tests were also included in the data. The definition we used for HA-CDI[1] did not change over the study periods. Genotyping was not performed.

Statistical analysis

HA-CDI rates were compared using a 1-tailed t test calculated using Stata Data Analysis and Statistical Software (STATA Corp, College Station, TX).

RESULTS

HA-CDI rates

The HA-CDI rate per 10,000 patient-days was reduced from 9.46 in 2010 to 4.45 in 2011 (53% reduction; P = .01; 95% confidence interval: 6.40–12.4; t = 2.491). Previously rates were stable at 5.281 in 2009 and 8.1 in 2010 (53% reduction; P = .002; 95% confidence interval: 7.58–10.8; t = 2.97). It should be noted that, of the 15 patients who were diagnosed with HA-CDI in 2011, 11 (73%) were placed in rooms that had not been treated with the PPX-UV device prior to occupation. Overall, 56% of discharged rooms received the UV light treatment. One reason some rooms were not treated was the simultaneous discharge of a number of patients and the limited number of devices. In addition, whereas most of our rooms are single occupancy, occasionally 2-bed rooms with 1 patient remaining could not be fully treated, although often the bathroom was treated. The at-risk population at our facility had a fairly stable median age (57.5–58.4 years), and our patient acuity index rose slightly (see Table 2).

Death and colectomy

During 2011, there was 1 attributable death, and there were no attributable colectomies, whereas there were 6 and 3, respectively, in 2010; 8 and 1, respectively, in 2009; and 4 and 1, respectively, in 2008.

DISCUSSION

The HA-CDI rate in 2011, during the use of PPX-UV, was significantly lower than during the previous 1 year and than the average of the previous 3 years. The inclusion of PCR data in 2011 would have increased our rate of positive tests, if all other factors were the

<table>
<thead>
<tr>
<th>Year</th>
<th>Quinolone-days</th>
<th>Quinolone-days/patient-days × 100 (Q/P)</th>
<th>Percent change (Q/P) from previous year</th>
</tr>
</thead>
<tbody>
<tr>
<td>2009</td>
<td>Ciprofloxacin-days 88.5</td>
<td>0.24</td>
<td>-2.6%</td>
</tr>
<tr>
<td></td>
<td>Levofloxacin-days 4,848</td>
<td>13.2</td>
<td>+28.5%</td>
</tr>
<tr>
<td></td>
<td>Total quinolone-days 4,936.5</td>
<td>13.5</td>
<td></td>
</tr>
<tr>
<td>2010</td>
<td>Ciprofloxacin-days 1,215.5</td>
<td>3.5</td>
<td>+1358%</td>
</tr>
<tr>
<td></td>
<td>Levofloxacin-days 2,819</td>
<td>8.1</td>
<td>-38.6%</td>
</tr>
<tr>
<td></td>
<td>Total quinolone-days 4,034.5</td>
<td>11.5</td>
<td>-14.8%</td>
</tr>
<tr>
<td>2011</td>
<td>Ciprofloxacin-days 1,527.5</td>
<td>4.5</td>
<td>+28.5%</td>
</tr>
<tr>
<td></td>
<td>Levofloxacin-days 2,265</td>
<td>6.7</td>
<td>-17.3%</td>
</tr>
<tr>
<td></td>
<td>Total quinolone-days 3,792.5</td>
<td>11.2</td>
<td>-2.6%</td>
</tr>
</tbody>
</table>

NOTE. Ciprofloxacin-days = ciprofloxacin doses administered divided by 2. Levofloxacin-days = levofloxacin doses administered. Quinolone-days = ciprofloxacin days + levofaxin days.
same, thus making a change in data collection or testing unlikely to have accounted for our results. Hospital average age and acuity index increased slightly between 2010 and 2011, which probably would have increased patient risk for HA-CDI (see Table 2).

Because antibiotic use—in particular levofloxacin—may be a risk factor for the development of HA-CDI, our quinolone usage was evaluated (see Table 1). Total quinolone use fell prior to the implementation of PPX-UV but remained relatively stable between the 1 year prior and the intervention year. Interestingly, levofloxacin use declined significantly during the previous 1 year without a major change in HA-CDI compared with the prior year (2009). Levofloxacin use continued to decline modestly in the study year, with a rise in ciprofloxacin use compared with the previous year. Given that a dramatic decline in levofloxacin use did not appear to affect the HA-CDI rate between 2009 and 2010, it appears unlikely that further changes in quinolone use accounted for the significant change in HA-CDI during the study year.

The total number of HA-CDI-related deaths and colectomies decreased substantially, with no colectomies attributable to HA-CDI occurring during the intervention year. Additionally, the rate of death because of HA-CDI declined. This may be attributable to the decrease in number of cases and/or to the severity of cases.

Whereas the goal was to use PPX-UV in every room at terminal cleaning, discharges often occurred simultaneously. With only 2 devices, and patients waiting to be admitted, some rooms were not treated. However, vacated precaution rooms were given priority for treatment with PPX-UV. In addition, there are approximately 30 rooms that may have double occupancy when the census is high. Because people should not be exposed to the PPX-UV light, 2-bed rooms vacated by 1 patient but housing the second could not be treated, although in those situations ES staff often used the device in the bathroom only.

Prior to implementation of PPX-UV, ES workers were trained in the use of the device as well as the important role the workers play in preventing illness and death. Although adding PPX-UV to their routine did increase their workload, as a group they felt great pride in being a part of the infection prevention team and playing an enhanced role in patient care. Although there were some initial issues with bulb longevity, the use of PPX-UV was quickly and easily integrated into the ES work schedule without additional staff.

The quasiexperimental design of this study makes definitive declaration of cause and effect impossible. Besides a continued decrease in the use of levofloxacin and an increase in ciprofloxacin use, no other significant antibiotic usage or infection prevention policy changes were known to occur. In addition, whereas the total number of subjects under surveillance was large, the total number of subjects with HA-CDI was small. The study does reflect, however, the successful implementation of this new technology in a real-world setting, with improved patient outcomes.

The dramatic reduction in infection, death, and colectomy due to HA-CDI after PPX-UV was added to standard infection prevention interventions makes this technique well worth investigating further in a large center with well-controlled variables.

### References


### Table 2

<table>
<thead>
<tr>
<th>Annual hospital and C difficile data</th>
<th>2008</th>
<th>2009</th>
<th>2010</th>
<th>2011</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number HA-CDI patients</td>
<td>32</td>
<td>36</td>
<td>33</td>
<td>15</td>
</tr>
<tr>
<td>Number HA-CDI attributable deaths</td>
<td>4</td>
<td>8</td>
<td>6</td>
<td>1</td>
</tr>
<tr>
<td>Number HA-CDI attributable colectomies</td>
<td>1</td>
<td>1</td>
<td>3</td>
<td>0</td>
</tr>
<tr>
<td>Rate HA-CDI per 10,000 patient-days</td>
<td>8.36</td>
<td>9.85</td>
<td>9.46</td>
<td>4.45</td>
</tr>
<tr>
<td>Rate of death for HA-CDI patients (number deaths/total HA-CDI)</td>
<td>0.13</td>
<td>0.22</td>
<td>0.18</td>
<td>0.067</td>
</tr>
<tr>
<td>Rate of colectomy for HA-CDI patients (number colectomies/total HA-CDI)</td>
<td>0.03</td>
<td>0.03</td>
<td>0.09</td>
<td>0.0</td>
</tr>
<tr>
<td>Number of community-associated CDI (inpatient and outpatient)</td>
<td>46</td>
<td>66</td>
<td>62</td>
<td>58</td>
</tr>
<tr>
<td>Percentage of discharge rooms treated with PPX-UV</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>56</td>
</tr>
<tr>
<td>Number (%) of HA-CDI patients whose rooms were not treated with PPX-UV prior to admission</td>
<td>32 (100)</td>
<td>36 (100)</td>
<td>33 (100)</td>
<td>11 (73)</td>
</tr>
<tr>
<td>Hospital patient-days</td>
<td>38,263</td>
<td>36,540</td>
<td>34,870</td>
<td>33,687</td>
</tr>
<tr>
<td>Hospital average age</td>
<td>57.9</td>
<td>58.4</td>
<td>57.5</td>
<td>58.3</td>
</tr>
<tr>
<td>Hospital acuity index (Diagnosis-related group case weight, Centers for Medicare and Medicaid Services)</td>
<td>0.0953</td>
<td>1.1265</td>
<td>1.1315</td>
<td>1.1386</td>
</tr>
</tbody>
</table>

*Comparison of HA-CDI rate in 2010 vs 2011: 53% reduction, P = .01; 95% confidence interval: 6.40-12.4; t = 2.491. The average HA-CDI rate for 2008-2010 was 9.22. Comparison of this rate with 2011 rate: 52% reduction; P = .002; 95% confidence interval: 7.58-10.8; t = 2.97.*
There was a positive association between HO-LabID MRSA bacteremia and previous history of MRSA (OR = 15.03, 95% CI 5.09-44.37), female gender (OR = 2.6, 95% CI 1.08-6.19 P), hemodialysis (OR = 3.7, 95% CI 0.98-13.98), and MPM >2.4 score (OR = 1.8, 95% CI 1.29-2.53).

CONCLUSIONS: Our findings highlight the importance of identifying patients with previous history of MRSA either by surveillance cultures and/or identifying them as such in their medical record; it also underlines the importance of decolonization interventions. The majority of the cases were located in the acute care units; these results point to the significance to expand interventions to prevent MRSA bacteremia to the acute care units.

1-105
Infection Prevention as the Driving Force for Antimicrobial Stewardship

Laura Parker, MSN, RN, CIC, Program Manager, Infection Prevention, Texas Health Harris Methodist Cleburne Hospital; Quentin Clark, Pharm.D., Director of Pharmacy, Texas Health Harris Methodist Hospital Cleburne; Barney Benner, RPh, Pharm D, Pharmacist, Texas Health HArris Methodist Hospital Cleburne

BACKGROUND: According to the CDC, 30-50% of antibiotics prescribed in hospitals are unnecessary or inappropriate. Antimicrobial stewardship is critical to the prevention of microbial resistance, and is an essential part of patient safety. It can be particularly challenging to promote stewardship in a small hospital without access to an infectious disease physician, but it is doable with the right team in place. Our team consists of the hospital pharmacists, the Chief Medical Officer, the Director of Quality, a physician champion and myself. Our team chose the CDC's, “Checklist for Core Elements of Hospital Antibiotic Stewardship Programs”, as our primary guide. We utilize days of therapy (DOT) and IV to PO conversion rates to measure our antibiotic utilization.

METHODS: The Pharmacy Director reviews redundant antimicrobial use during daily multidisciplinary rounds and makes recommendations when appropriate. The staff pharmacist’s review the IV to PO conversion list of patients that may meet the criteria for conversion. In addition, our physician stewardship champion writes a monthly newsletter and speaks to his peers about the importance of stewardship. Our DOT and IV to PO reports are our primary resources for compliance.

RESULTS: From the spring of 2014 to the fall of 2015 our DOT have steadily decreased. The target goal is below 1000 and we have moved from 1400 days to just below 1100. The IV to PO conversion report shows significant improvement as well.

CONCLUSIONS: Antimicrobial stewardship isn’t just about the number of antimicrobials used, nor is it just IV to PO conversions. It is also about ordering the right drug for the right length of time and for the right reason. The biggest challenges we encountered were physicians changing prescribing practices and documenting the indication and length of duration.

1-106
Reduction of Blood Culture Contamination Rate for a 300 Bed Community Hospital

Debbie A. Gibson, RN, BSN, CIC, Infection Preventionist, Norton Women and Kosair Children Hospital St. Matthews; Catherine R. Cooke, RN, MSN, CEN, Staff Nurse, Norton Women and Kosair Children’s Hospital

BACKGROUND: Blood culture contamination is a serious patient safety risk that can result in unnecessary antibiotic administration, increased cost to the patient, and prolong hospital stays. The hospital experienced a steady increase in blood culture contamination rates for 2012 and 2013, 2.36% and 2.84% respectively. The benchmark was set at ≤2%. The purpose of this project was to reduce blood culture contamination rate for the hospital.

METHODS: A review of that data on all the units in the hospital indicated that the emergency department (ED) had the highest percentage of blood culture contamination. In April 2014 a task force was developed to address the issue in the ED. Recommendations from the consultant were instituted. In July 2014, sterile gloves were added to the process. In addition the laboratory director notified ED staff immediately when a contaminated blood culture was identified. The responsible staff member(s) participated in a cause analysis to identify areas for improvement. A reduction in the overall hospital blood culture contamination rate occurred. It was decided to continue the monitoring for the ED in an attempt to further decrease the contamination rate. In April, 2015 a mask was added to the process.

RESULTS: The hospital ended 2014 with a 1.83% blood culture contamination rate. The 2014 rate for the ED was 2.83%. As of October 2015, the ED experienced 6 months with rates <2%. While the hospital’s corresponding rate drop in the hospital rate to 0.83%. Instituting the ED practices throughout the hospital has reduced the contamination rate on most units to 0%.

CONCLUSIONS: A reduction in the blood culture contamination rate from 2.83 to less than 2% was obtained. Modifications in the blood draw procedure were effective in accomplishing the goal. Participation of staff members performing the procedure in cause analysis was effective. The reduction in risk from the improved process reduced the risk of patient harm, reduced risk of unnecessary antibiotic administration, reduced risk of prolonged length of stay, and potential reduced costs. Review of the procedure by an outside expert provided insight into opportunities to improve cause analysis was effective. The reduction in risk from the improved process reduced the risk of patient harm, reduced risk of unnecessary antibiotic administration, reduced risk of prolonged length of stay, and potential reduced costs. Review of the procedure by an outside expert provided insight into opportunities to improve.

Antisepsis/Disinfection/ Sterilization

2-107
A Trial of Pulsed Xenon Ultraviolet Disinfection to Reduce C. Difficile Infection

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BACKGROUND: C. difficile is the most common cause of health care-associated infections (HAIs) in the United States. C. difficile spores
are resistant to routine hospital disinfectants and additional environmental cleaning measures may be required. **METHODS:** Pulsed xenon ultraviolet (PX-UV) disinfection was tested on three patient care units (intervention arm). Three similar units served as controls. The intervention and control arms each included two Hematology/Oncology units and one Medical-Surgical unit. Patient rooms on the intervention units received PX-UV in three 5-minute positions after terminal cleaning. Infection control measures (bleach use, hand hygiene and isolation compliance rates) were comparable for each arm. CDIs diagnosed by a polymerase chain reaction (PCR) test, were classified as HAIs and attributed to the unit if CDI was diagnosed > three days after admission or within four weeks of dismissal from that unit. Data was analyzed using a negative binomial regression model in Stata 12. **RESULTS:** Eighty-five percent of rooms in the intervention units were disinfected with PX-UV during the intervention. Baseline HAI CDI rates in the intervention and control arms were 18.3 and 20.1 per 10,000 patient days respectively. During the 6 months of PX-UV disinfection, the HAI CDI rate in the intervention units decreased to 11.2 per 10,000 patient days compared to 28.7 per 10,000 patient days in the control units (P = .03). The addition of PX-UV added an average of 25 minutes to the terminal cleaning process. **CONCLUSIONS:** There was a significant decrease in CDI HAIs over the intervention period. The addition of PX-UV did increase average terminal room cleaning time, but Environmental Services staff were still able to disinfect a high percentage of room on the intervention unit. Data will be monitored with hopes of continued positive results, but initial data are promising.

2-108
**Can Use of a Fluorescent Gel Monitoring Program Improve Compliance with Cleaning of Clinical Equipment?**

**Katherine A. Rhodes, RN, BSN, CIC, COIN-S, CHSP, Infection Prevention Manager, Texas Health Southwest**

**BACKGROUND:** Cleaning of clinical equipment between patient use is critical to preventing transmission of microorganisms in the healthcare setting. A baseline assessment of clinical equipment cleaning on inpatient areas was conducted in 2013 and found average compliance to be 50%. Direct observation had not been effective in improving compliance. Use of a fluorescent gel marking program had been successful with improving cleaning of patient rooms by environmental services personnel, and Infection Prevention theorized that this success could be replicated with clinical personnel cleaning responsibilities. **METHODS:** A risk assessment was performed to determine high risk and/or high touch devices which posed the greatest risk for patient-to-patient transmission of microorganisms. All clinical areas were included, including nursing units, emergency department, respiratory therapy, physical therapy, radiology, surgical services, and others. A goal was defined and data was included on departmental scorecards. A randomized process for marking equipment with fluorescent gel was implemented by infection preventionists, and checked on a subsequent shift or day. Compliance was defined as partial or full removal of the fluorescent mark on the device. **RESULTS:** Over 270 pieces of equipment were marked quarterly across 18 departments. Overall compliance improved from 58.6% at the end of 2013 to 89.3% at fourth quarter 2014. Quarters one through three of 2015 exceeded the 90% goal, with an overall year-to-date compliance rate of 92.2%. Multiple departments met 100% consistently in 2015. **CONCLUSIONS:** This study found that use of a fluorescent gel marking program improved compliance with cleaning of high risk and/or high touch devices by clinical personnel. Cleaning responsibilities for nursing and other clinicians are often overlooked or unclear. This monitoring program defined the expectations for clinical staff and drove improvement. Cleaning of clinical equipment in the healthcare setting is one piece of a program to prevent healthcare associated infections.

2-109
**Challenges in Assessing Effectiveness of No-Touch Disinfection Technology: An Evaluation of the Published Literature**

**Charles Dale Jr., BA, Research Associate, Xenex Disinfection Services; Sarah Simmons, BS, MPH, DrPH, CIC, Science Director, Xenex Disinfection Services; James Holt, BS, MS, Research Associate, Xenex Disinfection Services; Mark Stibich, PhD, Chief Scientific Officer, Xenex Disinfection Services**

**BACKGROUND:** UV disinfection systems are currently regulated by the United States Environmental Protection Agency (EPA) as a pesticidal device. To date, the EPA has provided no required mechanism/procedure for validation of UV disinfection claims. As a result, there are different strategies used in determining the efficacy of UV disinfection; lab effectiveness, environmental effectiveness and patient outcome effectiveness. **METHODS:** We reviewed the literature regarding assessment of no-touch technology to determine if there was a reliable method. **RESULTS:** The most common procedure quantifies the effects of UV disinfection in a third-party laboratory. Exposure methodologies vary across laboratories, leading to variation in results. Previous research found that variation in test methods impacts the final results. Numerous studies have attempted to quantify effectiveness in the actual hospital environment. The methodologies have been inconsistent in sampling techniques, cleaning before no-touch disinfection, organisms isolated, and use of quantitative vs. qualitative methods. Due to these differences, the results vary substantially from study to study. The disinfection efficacy ranges from 0.57 log10 - 2.87 log10 (average 1.59 log10, SD 0.55). Due to these inconsistencies, it is difficult for infection preventionists to rely of this type of research to make product selections. Eight non-randomized studies represent the largest body of evidence supporting no-touch disinfection. While these article have limitations due to the quasi-experimental methods employed, they collectively demonstrate that no-touch systems can be effectively employed to reduce infection rates in hospitals. Additionally, preliminary results from one randomized controlled trial have reported mixed results for reductions in infection rates. Full publication of these results will be instrumental in evaluating the effectiveness of no-touch systems. See Table 1. **CONCLUSIONS:** The authors suggest that the most effective method of evaluating no-touch disinfection systems is to assess the reported infection reductions in the literature.

2-110
**Development of a Microbiological Surveillance Program for Duodenoscopes**

**Jeana L. Houseman, MHSA, DLM(ASCP), Infection Preventionist, University of Minnesota Medical Center**

**METHODS:** A fluorescent gel was developed to evaluate the efficacy of no-touch technology to reduce infections associated with the use of duodenoscopes. A randomized controlled trial was conducted across four medical centers in the United States. All endoscopes were disinfected using a liquid-based disinfectant and PX-UV. The PX-UV system was used in the intervention arm and included a fluorescent gel marking program. A randomized process for marking equipment with fluorescent gel was implemented by infection preventionists, and checked on a subsequent shift or day. Compliance was defined as partial or full removal of the fluorescent mark on the device. **RESULTS:** Over 270 pieces of equipment were marked quarterly across 18 departments. Overall compliance improved from 58.6% at the end of 2013 to 89.3% at fourth quarter 2014. Quarters one through three of 2015 exceeded the 90% goal, with an overall year-to-date compliance rate of 92.2%. Multiple departments met 100% consistently in 2015. **CONCLUSIONS:** This study found that use of a fluorescent gel marking program improved compliance with cleaning of high risk and/or high touch devices by clinical personnel. Cleaning responsibilities for nursing and other clinicians are often overlooked or unclear. This monitoring program defined the expectations for clinical staff and drove improvement. Cleaning of clinical equipment in the healthcare setting is one piece of a program to prevent healthcare associated infections.
Evaluation of a pulsed xenon ultraviolet disinfection system to decrease bacterial contamination in operating rooms

Lynn El Haddad¹, Shashank S. Ghantoji¹, Mark Stibich¹,², Jason B. Fleming³, Cindy Segal⁴, Kathy M. Ware¹ and Roy F. Chemaly¹∗

Abstract

Background: Environmental cleanliness is one of the contributing factors for surgical site infections in the operating rooms (ORs). To decrease environmental contamination, pulsed xenon ultraviolet (PX-UV), an easy and safe no-touch disinfection system, is employed in several hospital environments. The positive effect of this technology on environmental decontamination has been observed in patient rooms and ORs during the end-of-day cleaning but so far, no study explored its feasibility between surgical cases in the OR.

Methods: In this study, 5 high-touch surfaces in 30 ORs were sampled after manual cleaning and after PX-UV intervention mimicking between-case cleaning to avoid the disruption of the ORs’ normal flow. The efficacy of a 1-min, 2-min, and 8-min cycle were tested by measuring the surfaces’ contaminants by quantitative cultures using Tryptic Soy Agar contact plates.

Results: We showed that combining standard between-case manual cleaning of surfaces with a 2-min cycle of disinfection using a portable xenon pulsed ultraviolet light germicidal device eliminated at least 70% more bacterial load after manual cleaning.

Conclusions: This study showed the proof of efficacy of a 2-min cycle of PX-UV in ORs in eliminating bacterial contaminants. This method will allow a short time for room turnover and a potential reduction of pathogen transmission to patients and possibly surgical site infections.

Keywords: Operating rooms, Environment cleanliness, Pulsed xenon ultraviolet, Between-cases mimicking

Background

About 400,000 surgical site infections (SSIs) are documented annually in the United States, with associated costs of around $21,000 per case [1, 2]. Prevalent organisms associated with SSIs, such as Staphylococcus aureus, Enterococcus species, Klebsiella spp., Pseudomonas aeruginosa, and Escherichia coli, can persist on surfaces from 1.5 h to more than 30 months [3]. Standard manual cleaning alone is not sufficient to eliminate these pathogens; only around 47% of surfaces are appropriately disinfected during between-case and end-of-day terminal manual cleaning [4]. Implementation of efficient environmental disinfection methods as a supplement to manual cleaning may aid in reducing the risk of wound contamination and subsequent infection, thus eliminating the possible transmission of pathogens to patients [5, 6].

The portable ultraviolet light germicidal device employing pulsed xenon lamps (PX-UV) has been shown to be a safe, easy-to-operate, and effective system in decreasing the number of pathogens [7]. PX-UV uses a xenon flash lamp to generate broad-spectrum, high-intensity ultraviolet light to deactivate and kill bacteria, spores, and viruses on high-touch surfaces in 5 min or less [7]. Two studies have shown that the use of PX-UV in addition to standard end-of-day manual cleaning helped reduce...
bacterial contamination levels on surfaces in the operating rooms (ORs) by 62% and 81% [8, 9].

Furthermore, it was shown that contamination in the OR increases with sequential cases, leading to a more contaminated environment for each subsequent patient during operative hours [9]. Hence, rapid and effective between-case cleaning could reduce environmental contamination, protecting subsequent patients during the same day of operation. While improved patient outcomes have been observed after PX-UV during nightly terminal cleaning practices [8, 9], no data are available on the impact of this technology when applied between surgical cases.

In this study, we aimed to determine the sufficient time required by the PX-UV device to reach environmental cleanliness.

Methods
This environmental sampling study was conducted at The University of Texas MD Anderson Cancer Center. The sampling occurred between the last end-of-case cleaning and the nightly standard terminal cleaning practices. Cleaning efficacy was assessed after 1, 2, and 8 min of PX-UV cycles using a PX-UV device (Xenex Disinfection Services). These cycle times were chosen based on proof-of-concept experiments conducted in the laboratory setting (data not shown). For each OR, high-touch surfaces were sampled at two distinct time points: after standard end-of-case cleaning and after PX-UV disinfection.

At the conclusion of surgical cases each day, the room was cleaned by OR staff according to standard end-of-case protocols (manual cleaning with ready-to-use germicidal wipes or diluted solution). Following this cleaning by not more than 1.5 h, samples from 5 high-touch surfaces (computer monitor, electrocautery unit, anesthesia cart, chair, and bed table controls) were collected for quantitative culturing using Tryptic Soy Agar contact plates. For non-flat surfaces, the plates were rolled so that their entire area came in contact with the high-touch surface. The ORs were then disinfected with a PX-UV device for 1, 2, or 8 min (10 rooms for each cycle time) at the head of the table, ensuring direct line of sight for the UV light for high-touch surfaces (Fig. 1). Following PX-UV disinfection, the same 5 high-touch surfaces were sampled at sites adjacent to the first sites using Tryptic Soy Agar contact plates. After 48-h incubation at 37 °C of the plates, colony counts were recorded. We sampled 30 ORs, generating 150 samples before PX-UV use and 150 samples after PX-UV. Table 1 gives a detailed description of all cases in each sampled OR (Table 1).

The pre-PX-UV samples were combined for analysis to remove any variance issue. Means, medians, and ranges of colony counts were recorded at each sampling period for statistical analysis. As the data were nonparametric, a Wilcoxon rank sum test was used to examine the differences between groups.

![Fig. 1 Schematic design of an operating room showing the accurate position of the PX-UV device (purple) to ensure direct line of sight of the UV light to the high-touch surfaces (identified as a to h).](image_url)
<table>
<thead>
<tr>
<th>OR PX-UV cycle time (minutes)</th>
<th>Mean c.f.u. before PX-UV</th>
<th>Mean c.f.u. after PX-UV</th>
<th>Total number of cases during the day</th>
<th>Consecutive case type</th>
<th>Last case type of the day before PX-UV</th>
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<tbody>
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<td>1 1</td>
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<td>2 1</td>
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<td>1.4 ↓ 2</td>
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<td>Wide Local Excision; Neck Dissection</td>
<td>Neck Dissection</td>
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<td>3 1</td>
<td>1.2</td>
<td>1.6</td>
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<td>Partial Nephrectomy</td>
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<td>4 1</td>
<td>2.3</td>
<td>1.4 ↓ 3</td>
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<td>Mastectomy, Wide Local Excision</td>
<td>Excision of lesion on back</td>
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<tr>
<td>5 1</td>
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<td>Laminectomy with stabilization</td>
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<td>6 1</td>
<td>2.8</td>
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<td>Nephrectomy</td>
<td>Diagnostic Laparostomy</td>
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<td>Thyroid with Neck Dissection</td>
<td>Closure of enterostomy</td>
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<tr>
<td>8 1</td>
<td>2.2</td>
<td>2.6</td>
<td>2</td>
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<td>Examination under Anaesthesia with biopsies</td>
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<td>Removal of tibial nail hardware &amp; complex closure</td>
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<tr>
<td>10 1</td>
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<td>Insertion of Port-A-Cath</td>
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<tr>
<td>11 2</td>
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<td>Partial Excision of genitalia with reconstruction</td>
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<tr>
<td>12 2</td>
<td>1.0</td>
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<td>2</td>
<td>closure of enterostomy</td>
<td>Partial colectomy</td>
</tr>
<tr>
<td>13 2</td>
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<td>2.2</td>
<td>1</td>
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<tr>
<td>14 2</td>
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<td>Tandem and Ovoid insertion</td>
<td>Tandem and Ovoid insertion</td>
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<tr>
<td>15 2</td>
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<td>Partial Lobectomy Liver and Hysterectomy</td>
<td>Partial Lobectomy Liver and Hysterectomy</td>
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<tr>
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<td>Diagnostic Laparotomy with CVC insertion</td>
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<td>17 2</td>
<td>2.2</td>
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<td>Experimental Laparoscopy with bowel anastomosis</td>
<td>Excision of groin lymph node</td>
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<tr>
<td>18 2</td>
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<td>Proctectomy, Hysterectomy and reconstruction</td>
<td>Proctectomy, Hysterectomy and reconstruction</td>
</tr>
<tr>
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<tr>
<td>20 2</td>
<td>1.4</td>
<td>0.4 ↓ 3</td>
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<td>Cranietomy</td>
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<tr>
<td>22 8</td>
<td>3.2</td>
<td>1.0 ↓ 2</td>
<td></td>
<td>Laparoscopic liver resection</td>
<td>Closure of enterostomy and Laparoscopic liver</td>
</tr>
<tr>
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<td>0.8 ↓ 2</td>
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<td>Port-A-Cath insertion</td>
<td>Diagnostic Laparotomy with liver biopsies</td>
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<td>Mastectomy with reconstruction</td>
<td>Segmental Mastectomy</td>
</tr>
<tr>
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<td>1.6 ↓ 1</td>
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<td>Mastectomy with reconstruction</td>
<td>Mastectomy with reconstruction</td>
</tr>
<tr>
<td>26 8</td>
<td>1.4</td>
<td>0.0 ↓ 3</td>
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<td>Diagnostic Laparostomy with Hysterectomy; Incision and Drainage cyst</td>
<td>Cystoscopy with biopsies</td>
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<tr>
<td>27 8</td>
<td>0.8</td>
<td>0.2 ↓ 2</td>
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<td>Laparoscopic Salpingo-Oopherectomy</td>
<td>Diagnostic Laparotomy with biopsies</td>
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<tr>
<td>28 8</td>
<td>2.2</td>
<td>0.6 ↓ 2</td>
<td></td>
<td>Thyroidectomy</td>
<td>Mastectomy</td>
</tr>
<tr>
<td>29 8</td>
<td>7.8</td>
<td>2.6 ↓ 1</td>
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<td>Partial colectomy with nephrectomy</td>
<td>Partial colectomy with nephrectomy</td>
</tr>
<tr>
<td>30 8</td>
<td>7.6</td>
<td>0.5 ↓ 1</td>
<td></td>
<td>Thoracotomy with Lobectomy and Pulmonary Arterial reconstruction</td>
<td>Thoracotomy with Lobectomy and Pulmonary Arterial reconstruction</td>
</tr>
</tbody>
</table>

Abbreviations: OR, Operating Room; PX-UV, pulsed xenon ultraviolet; c.f.u., Colony-forming units. The symbol “↓” indicates a decrease in c.f.u. after PX-UV.
Results
A total of 147 pre-PX-UV samples and 148 post-PX-UV samples measuring bacterial load obtained for the 5 high-touch surfaces were included in the analysis. Five plates (3 in the pre-PX-UV group and 2 in post-PX-UV groups) were discarded from the analysis as outliers because of counts that were too numerous to count (TNTC) and attributed to lab error, such as a dislodged cover plate. If included in the analysis, the outliers would have had undue leverage on the data for the intervention group that had no outliers (the 1-min group), and therefore the removal of the outliers was deemed conservative.

Table 2 depicts the changes in the colony-forming units (c.f.u.) between pre- and post-PX-UV use at different cycle times. A 1-min cycle of PX-UV did not generate a significant reduction in the level of contamination on the high-touch surfaces ($P = 0.594$). However, 2- and 8-min cycles showed significant reduction in the level of environmental contamination by decreasing the mean colony counts by 72.5% ($P = 0.0328$) and 73.1% ($P = 0.0075$), respectively (Table 2). A 2-min PX-UV cycle was as effective in eliminating an equal load of bacterial contamination when compared to an 8-min cycle.

Discussion
We found PX-UV disinfection effective in reducing colony counts when performed after standard cleaning. The 2- and 8-min PX-UV cycles produced equivalent and significant reduction of level of contamination when compared to standard OR cleaning alone and were more effective than the 1-min PX-UV cycle. We conclude that a 2-min cycle optimizes efficacy and efficiency.

A recent meta-analysis of financial impact on the United States healthcare system showed that SSIs contribute to 33.7% of the overall annual cost ($9.8 billion) of healthcare-associated infections [2]. By implementing this SSI prevention approach in the OR setting, contamination in the OR could be controlled during sequential cases, leading to a decontaminated environment for subsequent patients and may have positive impact on the rate of SSIs and associated costs.

PX-UV has been successfully used to reduce or eliminate pathogens such as vancomycin-resistant enterococci, Methicillin-resistant *Staphylococcus aureus* (MRSA), as well as *Clostridium difficile* on high-touch surfaces in patient rooms [10, 11]. In fact, PX-UV combined with quaternary ammonium removed 95% of *C. difficile* spores compared to a 70% of spores reduction when disinfecting patient rooms with bleach [10]. Moreover, PX-UV was 16 times more effective than manual cleaning in eliminating MRSA [12] and 100% effective against VRE [11]. The efficacy of this method has also been confirmed against fungi, *Bacillus anthracis*, and viruses such as Ebola virus [13]. In addition, PX-UV does not damage materials in hospital settings and is not transmitted through glass windows [10].

Another method for decontaminating OR rooms between cases is the use of improved hydrogen peroxide products (IHP) such as Activated Hydrogen Peroxide (Clorox Healthcare). Even though this disinfectant is effective in reducing the contamination level to around 84% of the baseline, it presents a major limitation, i.e., manual cleaning for about 2 to 4.5 h [14]. Manual cleaning is not predictable nor optimal being dependent upon the education of the cleaning personnel and the nurses [15, 16]. In fact, when cleaning, tools such as buckets, mop heads, and wipes can rapidly become contaminated and potentially transfer pathogens to other cleaned surfaces [7]. Also, the continual and recurrent use of the same chemical disinfectant can lead to the emergence of resistant microorganisms [7]. Moreover, the time spent on manually cleaning constitutes an important drawback in ORs where rapid bed turnaround time is crucial and entails operational costs for training specialized personnel. Finally, IHP costs around $175 per room, whereas the PX-UV device costs approximately $3 per room to operate, excluding labor costs in both cases [10].

The present study was limited to 5 high-touch surfaces. Other high-touch surfaces such as floors, light switches, cabinet handles, and doorknobs could be added to future studies. Additional limitations are the somewhat small sample size used in this study and the lack of bacterial identification to the species level by our use of TSA sampling plates, which are limited in detection to aerobic species. This study suggests the potential of PX-UV to be a promising alternative to manual cleaning in reducing the level of contamination in ORs and therefore reduce the incidence of SSI and concomitant costs.

### Table 2

<table>
<thead>
<tr>
<th>Timing of sampling</th>
<th>Samples taken (n)</th>
<th>Colony count (c.f.u.)</th>
<th>Reductiona (%)</th>
<th>$P$-value</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Mean</td>
<td>Min</td>
<td>Max</td>
</tr>
<tr>
<td>Pre PX-UV (all cycles combined)</td>
<td>147</td>
<td>3.19</td>
<td>0</td>
<td>55</td>
</tr>
<tr>
<td>Post 1-min PX-UV</td>
<td>50</td>
<td>1.70</td>
<td>0</td>
<td>14</td>
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<tr>
<td>Post 2-min PX-UV</td>
<td>49</td>
<td>0.88</td>
<td>0</td>
<td>9</td>
</tr>
<tr>
<td>Post 8-min PX-UV</td>
<td>49</td>
<td>0.86</td>
<td>0</td>
<td>7</td>
</tr>
</tbody>
</table>

*aReduction of mean colony count after PX-UV in comparison with pre-PX-UV mean colony count. PX-UV, pulsed xenon ultraviolet; IQR, Interquartile range; c.f.u., Colony-forming units; min, minimum; max, maximum*
bacteria only. Moreover, the impact of PX-UV use between cases on SSIs and identification of bacteria at the species level on ORs surfaces still need to be determined in future studies. Finally, an operational study that investigate the impact of the between-case use of PX-UV on OR case flow would be necessary.

Conclusions
In summary, our results suggest that supplementing standard cleaning procedures using a portable no-touch PX-UV system could be done routinely and rapidly between cases in the OR. A cycle of 2 min was sufficient in eliminating 70% or more of the bacterial load on inanimate high-touch surfaces, thus allowing short time for room turnover and potentially reducing pathogen transmission to patients and possibly SSI rates.

Abbreviations
c.f.u.: Colony-forming units; IHP: Improved hydrogen peroxide products; IQR: Interquartile range; max: Maximum; min: Minimum; OR: Operating rooms; PX-UV: Pulsed xenon lamps; SSIs: Surgical site infections; TNTC: Too numerous to count

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Availability of data and materials
All data generated or analyzed during this study are included in this published article.

Authors’ contributions
LEH, SSG, and MS conducted the experiments. Xenex Disinfection Services provided assistance with study design. MS provided the statistical analyses. LEH, MS, and RFC wrote and edited the manuscript. All authors read and approved the final manuscript.

Ethics approval and consent to participate
Not Applicable

Consent for publication
Not Applicable

Competing interests
RFC has received research grants from and acts as a consultant to Xenex Disinfection Services. M.S. is employed by Xenex Disinfection Services. All other authors declare that they have no competing interests.

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References

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What is This?
Impact of a multi-hospital intervention utilising screening, hand hygiene education and pulsed xenon ultraviolet (PX-UV) on the rate of hospital associated meticillin resistant *Staphylococcus aureus* infection

Sarah Simmons1*, Melissa Morgan2, Teresa Hopkins2, Kim Helsabeck2, Julie Stachowiak1, Mark Stibich1

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Key words: MRSA, disinfection, environment, bacterial contamination, healthcare associated infections, infection prevention and control, patient safety

Abstract

Standard approaches to meticillin resistant *Staphylococcus aureus* (MRSA) prevention have included hand hygiene and active surveillance. These approaches have shown mixed results. The addition of pulsed xenon ultraviolet (PX-UV) room disinfection for MRSA prevention is a novel approach. This new MRSA prevention method was implemented at an acute care hospital system in Greensboro, NC, USA. An MRSA screening programme was implemented over a six-month period from July 2011 to January 2012 to include all high-risk patients and the majority of surgical patients. A two-week hand hygiene education initiative was implemented in February 2011. The use of PX-UV for terminal cleaning of MRSA patient rooms was also implemented in February 2011. The rates of hospital associated MRSA (HA-MRSA) infections were monitored before and after implementation of all prevention efforts. The HA-MRSA rate decreased at the largest facility in the system by 57%, and for the entire healthcare system by 56% (p=0.001). The two smaller hospitals saw reductions of 51% and 66%, but the results were not statistically significant (p=0.1047 and p=0.2263). Implementing a PX-UV device in conjunction with active screening and hand hygiene was associated with a decrease in HA-MRSA rates. Studies on the individual effect of PX-UV on HA-MRSA rates are warranted.

Background

Meticillin resistant *Staphylococcus aureus* (MRSA) is a well-known pathogen within healthcare facilities, and its impact on patient outcomes is well documented (Muto et al, 2003; Siegel et al, 2007). Current methods of controlling MRSA transmission have focused on active surveillance and hand hygiene. Active surveillance programmes are used to rapidly identify patients who are colonised with MRSA on admission to the facility, and hand hygiene interventions are designed to prevent the horizontal spread of disease among patients. Although studies indicate that active surveillance for MRSA is effective (Jernigan et al, 1995; West et al, 2006), recent analysis has shown that the effect of screening on reducing MRSA transmission may be overestimated (Gurieva et al, 2012). Similarly, there is evidence that educating staff on hand hygiene has an impact on infection rates, but these decreases may not be sustained or apply to all infection types (Pittet et al, 2000; Gordon et al, 2005). In contrast to the success documented in these studies, there are multi-year studies that indicate there is no association between increasing hand hygiene rates or the use of alcohol-based hand rubs and infection rates (Eckmanns et al, 2006; Backmann et al, 2007). New methods of preventing the spread of infection may be required.

The role of the environment in transmitting infection is addressed as a risk factor in guidelines published by both the Society for Healthcare Epidemiology of America (SHEA) and the Hospital Infection Control Practices Advisory Committee (HICPAC) (Muto et al, 2003; Siegel, 2007). Seventy three per cent of hospital rooms that contained a patient with an MRSA infection will be contaminated after discharge (Boyce et al, 1997). It has been shown that patients in a room where the previous occupant had an MRSA infection are 1.4 times more likely to develop an MRSA infection than those in a room where the previous occupant did not have MRSA (Huang et al, 2006).
Ultraviolet light has been shown to be an effective method of enhanced environmental disinfection (Stibich, 2010). Disinfection with ultraviolet light is achieved by the creation of thymine dimers in the DNA of organisms in the environment. The presence of thymine dimers inhibits DNA replication and deactivates the organism. Pulsed xenon ultraviolet (PX-UV) is a disinfection method that emits high levels of germicidal UV-C light (Stibich, 2010). PX-UV differs from mercury vapour UV technology in that it is more intense and uses a broader UV range to achieve more effective decontamination. PX-UV has been used previously in healthcare settings to reduce environmental contamination levels and infection rates (Levin et al., 2011; Stibich et al., 2011). Testing of PX-UV disinfection systems has demonstrated the ability to achieve a 5-log reduction in MRSA within five minutes in a laboratory environment (Stibich et al., 2011).

**Methods**

A combination of hand hygiene education, active surveillance, and PX-UV disinfection was implemented at a tertiary care hospital. For this study, active surveillance was conducted by sampling the nares of patients and detecting the presence of MRSA using a polymerase chain reaction (PCR) test. For patients who were identified as being MRSA colonised, a decolonisation protocol of antimicrobial nasal ointment and chlorhexidine bathing was implemented for five days. Targeted active surveillance was implemented on two units in July 2010, and was instituted for all admissions in January 2011. In addition to admission surveillance, active screening was instituted prior to selected surgeries in February 2011, and the majority of inpatient and outpatient surgeries in June 2011.

Computer-based learning for hand hygiene was assigned to all hospital staff in January 2011, with a mandatory completion date of February 2011. All current staff completed the hand hygiene education module, as well as staff hired after the mandatory completion date. Hand hygiene was monitored by direct observation on a monthly basis by the infection prevention department. Prior to the computer-based learning, hand hygiene compliance rates ranged from 70–80%. After the education was provided, rates increased to approximately 90%, and this rate was sustained throughout the intervention period.

PX-UV was implemented in February 2011 for terminal cleaning of rooms that housed a patient with an MRSA infection. Patients who were identified as colonised via active surveillance were not included in the PX-UV disinfection group owing to staffing limitations. The PX-UV device has been described elsewhere (Stibich et al., 2011). In this case, the device was used for three positions of five minutes each per patient room. These changes were implemented across all three facilities in the system on the same timeline.

Three facilities participated in the intervention: a 536-bed acute care hospital, a 175-bed community hospital, and a 66-bed community hospital. The rate of hospital associated MRSA infection (HA-MRSA) was compared before and after the implementation of the combined interventions of active surveillance, hand hygiene education, and PX-UV disinfection. Infection rates were available from October 2009 to January 2011 for baseline data, and from February 2011 to August 2012 for the intervention period. MRSA infection status was determined with clinical cultures using the definitions provided by the Centers for Disease Control and Prevention (CDC, 2013). For the purposes of analysis, the intervention was considered to be fully implemented in February 2011. The rates are compared using Wilcoxon rank sum analysis. Analyses were done on the combined data and the facility-specific data.

**Results**

Table 1 shows the facility descriptions. Table 2 shows the cumulative and facility-specific HA-MRSA rates before and after the bundled intervention. The cumulative analysis shows a 57% reduction in the...
HA-MRSA rate. For the 536-bed facility, the reduction was 56%; for the 175-bed facility, the reduction was 51%; and for the 66-bed facility, the reduction was 66%. Overall, it is estimated that 68 HA-MRSA infections were prevented. Both the cumulative and the 536-bed facility reductions were statistically significant (p=0.001 and p=0.0012, respectively). For the 175-bed facility and the 66-bed facility, the change in rate was not statistically significant (p=0.1047 and p=0.2263, respectively).

Discussion

The analysis showed a statistically significant reduction in HA-MRSA cumulatively and in the 536-bed facility. HA-MRSA cases were relatively rare at the 175-bed and 66-bed facilities, which may have contributed to the lack of statistical significance. The implantation of this combination of interventions was associated with a reduction in HA-MRSA; however, it is difficult to discern the effects of individual components. The potential impact of hand hygiene and MRSA screening combined on HA-MRSA rates is controversial. It is likely that the addition of the PX-UV environmental disinfection was a critical contributor to the result. The impact of the PX-UV environmental disinfection system alone, however, was not studied in this project. This study indicates that the use of PX-UV technology, as part of a multiple intervention approach, is an effective method of reducing the rate of hospital associated MRSA infections. Studies assessing the effectiveness of PX-UV as a stand-alone intervention are needed.

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Declaration of conflicting interests

Sarah Simmons is an employee of Xenex Healthcare Services. Mark Stibich and Julie Stachowiak are employees and shareholders in Xenex Healthcare Services.

References


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They’re used primarily to decontaminate the surfaces in the 11 ORs, for daily terminal cleaning, after dirty cases — a hernia repair that follows a colonoscopy, for example — and after any procedure involving a patient known to have an infection. One of St. Cloud’s surgeons insists that a robot zap
his room clean before every total joint case he performs (see “UV Robot Key to Surgery Center Doing Total Joints” on page 38). And at least once a week after hours, they station a robot in just about every room in the surgery center: the equipment room, the substerile room, the garbage room, the fluid suction device docking room, even the restrooms, the waiting room and the staff lounge, says Julie Tonsager, RN, St. Cloud’s operating room team leader.

“Patient safety is our top priority,” says Ms. Tonsager. “We clean the rooms with traditional cleaning methods, but there are always nooks and crannies that are hard to reach. And the germs are getting tougher, so it was important for us to take the battle against infections to the next level, to ensure our patients receive the best care.”

Studies show that hospital cleaning teams using standard cleaning practices aren’t able to disinfect all the surfaces in patient rooms, with more than half of the surfaces remaining untouched.
Missed a spot?

Wheeling a germ-zapping robot into the OR before you wheel the patient in is not an indictment against manual cleaning, but an admission that manually applying a liquid disinfectant to the surface with a cloth, wipe or mop is far from foolproof. The problem with manual cleaning is not the efficacy or the agents used — it’s about ensuring that adequate formulation, distribution and contact time occurs repeatedly in a busy environment ... and that nothing gets missed, especially with the rise of multi-drug-resistant organisms, says Ms. Tonsager.

“We do our normal cleaning [before we use the robots], but we’re all human,” she says.

Studies have shown that manual cleaning disinfects only 48% of room surfaces, while UV disinfection can get rid of 99.99% of pathogens. Studies have also shown that environmentally friendly UV light penetrates cell membranes of superbugs, viruses and bacteria, preventing them from replicating or mutating.

“At certain wavelengths, UV light will break the molecular bonds in DNA, thereby destroying the organism,” William A. Rutala, PhD, MPH, and colleagues conclude in his 2010 research paper, “Room Decontamination with UV Radiation,” published in *Infection Control and Hospital Epidemiology*.

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Some superbugs such as *Clostridium difficile* are showing resistance to chemical disinfectants, making them even more difficult to eliminate. Others, like CRE, have developed a resistance to antibiotics, making them nearly impossible to treat. When added to routine cleaning, UV light room disinfection systems let you destroy viruses, bacteria and bacterial spores in the patient environment without contact or chemicals. UV light penetrates the cell
The walls of microorganisms. Their DNA is instantly fused so that they are unable to reproduce or mutate, effectively killing them on surfaces and in the air without contact or chemicals.

Although bleach is routinely used in her ORs, it requires 10 minutes of drying time for adequate sporicidal effect, says Lou Ann Bruno-Murtha, DO, medical director of infection prevention and division chief of infectious diseases for the Cambridge (Mass.) Health Alliance. “UV light is able to penetrate spores that are quite hardy,” says Dr. Bruno-Martha. “If a surface is missed, or not wiped proper...
ly with chlorine bleach, UV provides another level of security.”

**Selective use**

When doing same-day, elective procedures on healthy patients, it’s fair to wonder how germ-zapping robots will impact your turnover times. “Time is a key factor,” says Ms. Tonsager. “We like to turn over our operating room in 15 to 20 minutes. In the OR, time is money.”
At Cooley Dickinson Hospital in Northampton, Mass., they’d like to run the UV robot after every surgery, but studies show that OR contamination in the room is cumulative over time and increases after the third case. “We’re trying to use it at least at that interval,” says Joanne Levin, MD, FSHEA, the medical director of the department of infection prevention at Cooley.

The Xenex system that St. Cloud uses takes 5 to 10 minutes on average per room, depending on room size (the robot’s UV has a 14-foot radius). Another leading UV disinfection device, Tru-D SmartUVC, short for Total Room Ultraviolet Disinfector, usually takes 30 to 40 minutes. After a manual cleaning, you wheel Tru-D into the center of the OR, and the robot’s sensors gauge the size of the room and adjust the dose accordingly, says the company.

All UV systems are not created equal. The Xenex has a shorter cycle time of 5 minutes, but a staff member has to reposition the device after an initial cycle, depending on space and room geometry. With Tru-D, you set it and forget it, but it takes a bit longer. Tru-D can precisely calculate room UVC dose to compensate for room size, shape, color and contents for proper thorough disinfection, even reaching surfaces in the shade or in the shadows, says the company. It can disinfect an entire room, from top to bottom, from a single location so the operator can move onto other tasks during the disinfection process.

UV light can only disinfect what it touches. UV light travels in straight lines, so there’s reduced efficacy in areas that are out of the unit’s direct line of sight. Having to position a single unit in multiple areas to target several surfaces could add to disinfection times.

Another important distinction between the portable products is how they create UV light. Xenex uses pulsed UV light, while Tru-D and the Clorox Healthcare Optimum-UV System use mercury bulbs to create UV light. Other systems use aerosolized hydrogen peroxide, hydrogen peroxide vapor, cluster ions and ozone gas to target areas your staff might have missed.

Many say UV systems are best suited for terminal cleaning at the end of the surgical schedule, and occasionally after cases involving high-risk patients with
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**It’s the environment**

Interest in understanding the role of the OR environment in transmission of surgical site infections has increased greatly in recent years. Poor hand hygiene certainly plays a supporting role, but there’s a growing awareness that the environment is getting patients sick. *The room is the problem*, they say. When Patient A leaves the room and you clean the room for Patient B, studies show that less than 50% of room surfaces are untouched. There’s enough contaminant left when patient A leaves the room to pose a threat to infect Patient B. *C. diff*, methicillin-resistant *Staphylococcus aureus* (MRSA) and other pathogens can live on surfaces for 5 months.

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_E-mail doconnor@outpatientsurgery.net._
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Pulsed-xenon ultraviolet light disinfection in a burn unit: Impact on environmental bioburden, multidrug-resistant organism acquisition and healthcare associated infections

Caroline Green a, Jeremy C. Pamplin b, Kristine N. Chafin b, Clinton K. Murray a,c, Heather C. Yun a,c,*

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A B S T R A C T

Portable pulsed xenon ultraviolet disinfection (PPX-UVD) may reduce healthcare associated infections (HAI). There is limited data to inform use in burn intensive care units (BICU), where multidrug-resistant organisms (MDRO), especially gram negative rods (GNR), commonly cause disease. We evaluated PPX-UVD effects on environmental bioburden and rates of HAI and MDRO acquisition in a BICU. PPX-UVD was used for 3 months after standard cleaning of patient and operating rooms (ORs). Settle and touch plates in patient rooms and ORs were obtained after standard cleaning, pre-and post-PPX-UVD. HAI and MDRO acquisition were evaluated 1 year prior to and for 3 months periods before, during, and after PPX-UVD. 110 touch and settle plates (33 pre- and 30 post-PPX-UVD) were obtained after standard cleaning, pre- and post-PPX-UVD. After PPX-UVD, environmental samples with any growth decreased (48% vs 31%, p=0.02), as did mean colony count/sample (2.8 pre- vs 1.6 post-, p=0.03). The 379 colonies largely represented skin commensals, without identified MDRO. Following PPX-UVD, no changes in device-associated infections, overall MDRO, or MDR GNR were seen, though a prolonged interval without healthcare-associated Clostridium difficile infection was observed. PPX-UVD in a BICU reduced overall environmental bioburden, without a statistically significant impact on HAI or MDRO.

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Abbreviations: PPX-UVD, portable pulsed xenon ultraviolet disinfection; HAI, healthcare associated infections; BICU, burn intensive care unit; MDRO, multidrug-resistant organisms; GNR, gram negative rods; CDI, Clostridium difficile infection; NHSN, National Healthcare Safety Network; UVC, Ultraviolet-C; MRSA, methicillin-resistant S. aureus; VRE, vancomycin-resistant enterococci; HA-CDI, healthcare-associated Clostridium difficile infections; CLABSI, central line associated bloodstream infection; CAUTI, catheter associated urinary tract infection; VAP, ventilator associated pneumonia; BAL, bronchoalveolar lavage; ORD, occupied bed days.

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1. Introduction

Healthcare associated infections (HAI) are a major cause of morbidity and mortality worldwide. Critical illness and disruption of host defense mechanisms place burn patients at high risk of infections, particularly with gram-negative rods (GNR), including multidrug-resistant organisms (MDRO) [1]. Infections account for the majority of deaths in patients who survive initial resuscitation [2, 3]. National Healthcare Safety Network (NHSN) data report higher baseline rates of HAIs in burn units compared to other types of intensive care units (ICUs) [4]. Staphylococcus aureus and GNR pathogens including Pseudomonas aeruginosa, Acinetobacter baumannii, and Klebsiella pneumoniae are commonly associated with infections in this population, with increasing rates of resistance over the course of hospitalization [5, 6]. Clostridium difficile infection has historically been less common in this center’s burn environment compared to other units, although rates have increased in recent years with introduction of PCR assays as well as changes in patient demographics to include more civilian transfer patients with complex wounds [7].

There has been much interest in the development of effective environmental disinfection strategies to prevent HAIs [8]. Contaminated surfaces act as reservoirs for pathogens, which can then be transmitted to patients. It is estimated that 20% of HAI may be driven by cross-transmission from the hospital environment, though these estimates may not apply to burn units, where patients’ wounds and the widespread use of invasive devices lead to high colonization and infection rates [9]. In a previous evaluation of environmental bioburden in this center’s burn unit, organisms have been cultured from 76% of environmental surfaces in occupied patient rooms [10]. A recent evaluation of airborne bacteria in a burn unit demonstrated significant dispersion created by bed and dressing changes, and numerous burn outbreak investigations have documented widespread environmental contamination with outbreak-strains of GNR including A. baumannii and P. aeruginosa [11-13]. Standard terminal cleaning involves manual application of chemicals to surfaces, which has numerous limitations, is prone to error, and up to 50% of surfaces may not be adequately disinfected during standard cleaning protocols [14]. Ultraviolet-C (UVC) light is broadly active against HAI pathogens, and no-touch devices using UVC generated by mercury or pulsed-xenon bulbs are becoming increasingly used as adjuncts to manual cleaning. Evaluations of UVC disinfection have demonstrated reductions in environmental pathogens, including methicillin-resistant S. aureus (MRSA), vancomycin-resistant enterococci (VRE) and C. difficile from hospital environment surfaces [15, 16].

Clinical data have also demonstrated reductions in infectious complications following implementation of UVC disinfection. One evaluation of UVC light disinfection hospital-wide resulted in a 53% reduction in healthcare associated C. difficile infections (HA-CDI), and another demonstrated a 70% reduction in HA-CDI cases in the ICU [17, 18]. Another study demonstrated an 87% reduction in ICU VRE rates, and a combined MDRO (including VRE, MRSA, and C. difficile) rate reduction of 61% [19]. However, no published data exist to date reporting on efficacy of portable pulsed-xenon ultraviolet disinfection (PPX-UVD) in burn units, either for reductions in environmental contamination or toward HAI or MDRO acquisition. Similarly, the role of PPX-UVD in reducing gram-negative infections has not been specifically evaluated.

2. Material and methods

The study entailed 2 aims. The primary aim was an evaluation of surface and air microbial contamination in inpatient rooms and ORs within an American Burn Association accredited burn center after standard cleaning, then before and after use of PPX-UVD. The secondary aim was an assessment of NHSN-defined HAI rates, MDRO acquisition, and clinical bioburden; the latter defined as all positive bacterial cultures from BICU patients in the time frames of interest. PPX-UVD was delivered after routine housekeeping disinfection via a device (Xenex Healthcare Services, San Antonio, TX) containing a xenon flash lamp emitting both the germicidal light spectrum of 200-280 nm UVC light as well as the visible light spectrum. Typical cycle lengths were five minutes, with four positions per patient room/anteroom/bathroom combination and two for shower rooms/ancillary areas. Cycle lengths were ten minutes for ORs with two positions per room. PPX-UVD was used in patient rooms when vacated for a procedure and after discharge, and in ORs/shower rooms/ancillary areas daily.

The burn unit contains 16 ICU patient beds and provides regional and referral burn care including patients transferred from overseas for their injuries. Patients predominantly are admitted for thermal injury, although there are occasional admissions for trauma or medical illness which undergo specialized wound care. Patients injured overseas generally arrive about 4 days after their injuries are sustained, while local and regional referrals present hours to days after burn. Standard care includes early resuscitation followed by wound excision and grafting. Vancomycin and amikacin are routinely used perioperatively, with topical antibiotics per staff discretion. Other routine infection control measures include private rooms, universal contact precautions, and strict hand hygiene. Central lines are routinely exchanged every five days or earlier if there is concern for infection. The burn center has dedicated housekeeping staff. Patient care equipment is cleaned after use with hospital approved disinfectants. Housekeeping cleans the room with approved disinfectants at least once per shift. At discharge or upon transfer to another unit, the patient room is cleaned in its entirety with a hospital approved disinfectant, including with a hospital approved bleach product if the occupying patient had CDI. Burn showers are also cleaned after each use.

2.1. Assessment of environmental microbial contamination

Inpatient rooms (n=9) and ORs (n=2) were evaluated at the beginning of a 3 month intervention period using PPX-UVD throughout the ICU. Bacterial contamination levels were assessed on 5 high-touch surfaces in inpatient rooms (bedrail, bathroom handrail, bedside monitor, documentation station, and door handle) and in ORs (OR table, back table, anesthesia machine, supply cabinet doors, and documentation station)
after standard terminal cleaning and again after PPX-UVD. Microbiologic sampling using contact and settle plates was performed in inpatient rooms after terminal cleaning the day of discharge, with the discharged patient having occupied the room for a minimum of 48h. In ORs, sampling with contact and settle plates occurred after terminal cleaning following ≥1 completed procedure within the previous 24h.

The difference in organism recovery from high touch surfaces was examined using MacConkey agar contact plates (Hardy Diagnostics, Santa Maria, California, product number: P47). The contact plates were incubated for 48h and read according to manufacturer’s instructions. The difference in airborne contamination in inpatient rooms and ORs was evaluated using 3 TSA agar petri dishes (“settle plates”) positioned as closely as possible to patient care spaces without disrupting provision of care. Each plate was left uncovered for 8-12h, then covered and incubated for 48h and read according to manufacturer’s instructions.

Contact plates and settle plates were collected on-site and evaluated at Central Texas Veterans Health Care System, Olin E. Teague Veterans’ Medical Center, Temple, Texas. Colonies were counted and underwent basic identification based on morphology/gram stain, with further workup (speciation, susceptibilities) performed if the isolate was consistent with a potential HAI pathogen, defined as S. aureus, Enterococcus spp., or any GNR.

2.2. Assessment of HAI rates, MDRO acquisition, and clinical bioburden

NHSN-defined HAI rates and MDRO acquisition in the burn ICU, as monitored routinely by infection prevention and without any links to individual patient information, were also assessed. The HAI data included all device associated infections, to include central line associated bloodstream infections (CLABSI), catheter-associated urinary tract infections (CAUTI), and ventilator-associated pneumonias (VAP), expressed as number of events per 1000 device days. MDRO acquisition was defined per NHSN criteria, including both incident colonization and infection, and both HAI rates and MDRO rates were collected via standard institutional surveillance policies [20,21]. A “clinical bioburden” endpoint (including positive cultures from the BICU, not excluding duplicates, and obtained during the study periods) was evaluated as an approximation of colonization and infection in BICU patients and as an assessment of pressures which might impact MDRO rates. These data were generated via electronic health record query of all BICU bacterial cultures from any site (surveillance, respiratory, bronchoalveolar lavage (BAL), wound, blood, body fluid, stool, urine, etc.) and C. difficile stool PCR results obtained from de-identified BICU patients during the study periods. Unit census data was obtained to generate a rate of positive cultures per 1000 occupied bed-days. In evaluation of HAI, MDRO acquisition, and clinical bioburden, 3 month study periods were assessed, to include a pre-intervention control period 1year prior to the intervention (December 2013-February 2014), an immediate pre-intervention control (September 2014-November 2014), the intervention period itself from December 2014 to February 2015 (after a 2-week wash-in period during which device use was inconsistent, and including a 2-week wash-out period after discontinuation), and an immediate post-intervention control (March 2015-May 2015).

2.3. Primary data analysis

Basic descriptive statistics were used to summarize the findings. Categorical variables were compared by chi-squared testing or Fisher’s exact test where appropriate. Statistical significance was set at p < 0.05 (two tailed). Statistical analysis was performed using existing software (SPSS, version 19.0, IBM SPSS).

3. Results

3.1. Microbiology data

Nine inpatient rooms and 2 ORs had air (n=63) and surface sampling (n=110) before and after PPX-UVD (Table 1). Prior to PPX-UVD, samples from bathroom hoppers, bedside monitors and door handles were most heavily contaminated. After PPX-UVD, total samples (including both touch and settle plates) with any growth significantly decreased (48% vs 31%, p=0.02), as did surface growth alone (51% vs 33%, p=0.05). Including both air and surface samples, mean microbial density (heterotrophic plate count) per sample was tabulated prior to PPX-UVD as 2.75 colonies/sample. After PPX-UVD, mean microbial density was reduced to 1.61 colonies/sample (p=0.03) (Fig. 1).

3.2. Environmental bioburden

A total of 379 colonies were isolated from air and environmental surfaces (Table 2). All but 4 bacteria were consistent with skin commensals. Two colonies of mold were grown. Neither of the 2 GNR, Sphingomonas paucimobilis and Moraxella osloensis, were common HAI pathogens or MDRO.

3.3. NHSN-defined HAI and MDRO

Comparing VAP, CLABSI, and CAUTI rates during the intervention period to combined rates from control periods, no statistically significant changes in the rates of these device-associated HAI were observed, either individually, or as a combined endpoint including total numbers of device-associated infections/1000 device-days (Table 3).

There was no significant decrease in the overall acquisition of MDRO or MDR GNR, following introduction of PPX-UVD (Table 4). However, after introduction of PPX-UVD, the BICU experienced the longest interval without HA-CDI between 2013 and 2015. The median time between HA-CDI cases from February 2013 through December 2014, when PPX-UVD began, was 65.5 days (range 2-148); following the PPX-UVD intervention, the next HA-CDI did not occur for 290 days following the previous case. During this time, HA-CDI cases in the rest of the hospital remained stable. Though no cases in the BICU were observed during the intervention and three month post-intervention period, this decrease did not achieve statistical significance.

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### Table 1 – Review of number of colonies and percentages of plates with growth before and after portable pulsed-xenon ultraviolet light disinfection (PPX-UVD).

<table>
<thead>
<tr>
<th></th>
<th>Pre-PPX-UVD (# colonies)</th>
<th>N (%) with any growth</th>
<th>Post-PPX-UVD (# colonies)</th>
<th>N (%) with any growth</th>
<th>p value (any growth)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Surface samples (touch plates)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Operating room (n=2)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Anesthesia machine</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>Back table</td>
<td>2</td>
<td>1 (50%)</td>
<td>0</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>Cabinet</td>
<td>2</td>
<td>1 (50%)</td>
<td>5</td>
<td>2 (100%)</td>
<td></td>
</tr>
<tr>
<td>Documentation station</td>
<td>1</td>
<td>1 (50%)</td>
<td>0</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>Table</td>
<td>2</td>
<td>1 (50%)</td>
<td>0</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>Inpatient rooms (n=9)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bathroom hopper</td>
<td>37</td>
<td>6 (67%)</td>
<td>28</td>
<td>6 (67%)</td>
<td></td>
</tr>
<tr>
<td>Bedrail</td>
<td>3</td>
<td>3 (33%)</td>
<td>3</td>
<td>2 (22%)</td>
<td></td>
</tr>
<tr>
<td>Bedside monitor</td>
<td>97</td>
<td>2 (22%)</td>
<td>1</td>
<td>1 (11%)</td>
<td></td>
</tr>
<tr>
<td>Documentation station</td>
<td>10</td>
<td>7 (78%)</td>
<td>6</td>
<td>3 (33%)</td>
<td></td>
</tr>
<tr>
<td>Door handle</td>
<td>65</td>
<td>6 (67%)</td>
<td>78</td>
<td>3 (33%)</td>
<td></td>
</tr>
<tr>
<td>Air samples (settle plates)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Operating room (n=6)</td>
<td>2</td>
<td>2 (33%)</td>
<td>1</td>
<td>1 (17%)</td>
<td></td>
</tr>
<tr>
<td>Inpatient rooms (n=27 before, n=24 after)</td>
<td>21</td>
<td>12 (44%)</td>
<td>13</td>
<td>7 (29%)</td>
<td></td>
</tr>
<tr>
<td>Surface totals (n=110)</td>
<td>219</td>
<td>28 (51%)</td>
<td>123</td>
<td>18 (33%)</td>
<td>0.05</td>
</tr>
<tr>
<td>Air totals (n=63)</td>
<td>23</td>
<td>14 (42%)</td>
<td>14</td>
<td>8 (27%)</td>
<td>0.19</td>
</tr>
<tr>
<td>Total</td>
<td>242</td>
<td>42 (48%)</td>
<td>137</td>
<td>26 (31%)</td>
<td>0.02</td>
</tr>
</tbody>
</table>

#### 3.4. Clinical bioburden data

All positive clinical bacterial cultures obtained from de-identified BICU patients were assessed during 3 month intervals 1 year prior to, 3 months prior to, during, and after trial of PPX-UVD (Table 5). During the intervention period, there was a significant decrease in total MDRO per 1000 occupied bed days (OBD) (p=0.03), apparently largely driven by an unusually high number in the post-intervention period. During the intervention period, there were trends toward reductions in percentage of MDRO among all bacteria (p=0.07) as well as the rate of MDR GNR per 1000 OBD (p=0.07). There were 2 clinical samples positive for _C. difficile_ in the initial 2-week wash-in period of PPX-UVD use, and another community-associated case halfway through the intervention period, with none in the post-intervention period.

![Fig. 1 – Mean heterotrophic plate counts pre- and post-PPX-UVD.](image)

Mean heterotrophic plate counts from air (n=33 settle plates before portable pulsed-xenon ultraviolet light disinfection [PPX-UVD] and n=30 after PPX-UVD) and surfaces (n=55 touch plates both before and after PPX-UVD), as well as total plates (n=88 before PPX-UVD and n=85 after PPX-UVD).
Table 2 – Organisms isolated from surfaces and air (touch and settle plates), total number of colonies of each organism, and source of cultures positive for each organism.

<table>
<thead>
<tr>
<th>Organism</th>
<th># Total colonies</th>
<th>Sites (n from each site)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bacillus spp.</td>
<td>9</td>
<td>Air (3) Bathroom hopper (2) Bedrail (1) Documentation station (2) Door handle (1)</td>
</tr>
<tr>
<td>Coagulase negative staphylococci</td>
<td>329</td>
<td>Air (24) Bathroom hopper (57) Bedrail (2) Bedside monitor (98) Cabinet (1) Documentation station (12) Door handle (135)</td>
</tr>
<tr>
<td>Micrococcus spp.</td>
<td>8</td>
<td>Air (2) Door handle (6)</td>
</tr>
<tr>
<td>Corynebacterium aurinocosum</td>
<td>1</td>
<td>Air</td>
</tr>
<tr>
<td>Dietzia cinnamens</td>
<td>1</td>
<td>Documentation station</td>
</tr>
<tr>
<td>Moraxella osloensis</td>
<td>1</td>
<td>Air</td>
</tr>
<tr>
<td>Sphingomonas paucimobilis</td>
<td>1</td>
<td>Door handle</td>
</tr>
<tr>
<td>Mold</td>
<td>3</td>
<td>Air (3) Cabinet (2)</td>
</tr>
<tr>
<td>Other presumed environmental isolates</td>
<td>26</td>
<td>Air (3) Back table (2) Bathroom hopper (6) Bedrail (3) Cabinet (5) Documentation station (5) Table (2)</td>
</tr>
<tr>
<td>(listed as large gram positive cocci, gram-positive rods, or unknown/not described)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 3 – Device-associated infections reported during 3 month control periods and trial of portable pulsed-xenon ultraviolet light disinfection (PPX-UVD).

<table>
<thead>
<tr>
<th>Control: 1 year prior</th>
<th>Control: pre-PPX-UVD</th>
<th>Intervention: PPX-UVD</th>
<th>Control: post-PPX-UVD</th>
<th>P-Value*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Central line days (utilization ratio)</td>
<td>840 (0.89)</td>
<td>528 (0.80)</td>
<td>542 (0.85)</td>
<td>531 (0.88)</td>
</tr>
<tr>
<td>CLABSI rateb</td>
<td>3.57</td>
<td>9.47</td>
<td>1.85</td>
<td>3.77</td>
</tr>
<tr>
<td>Foley days (utilization ratio)</td>
<td>878 (0.93)</td>
<td>555 (0.85)</td>
<td>558 (0.88)</td>
<td>523 (0.87)</td>
</tr>
<tr>
<td>CAUTI rateb</td>
<td>4.56</td>
<td>7.21</td>
<td>1.79</td>
<td>1.91</td>
</tr>
<tr>
<td>Ventilator days (utilization ratio)</td>
<td>634 (0.67)</td>
<td>398 (0.61)</td>
<td>381 (0.60)</td>
<td>434 (0.72)</td>
</tr>
<tr>
<td>VAP rateb</td>
<td>3.15</td>
<td>2.51</td>
<td>7.87</td>
<td>2.69</td>
</tr>
<tr>
<td>Overall device-associated infection rate</td>
<td>3.82</td>
<td>5.40</td>
<td>3.38</td>
<td>2.69</td>
</tr>
</tbody>
</table>

Utilization ratios: number of device-days/occupied bed days. CLABSI: central line associated bloodstream infection; CAUTI: catheter associated urinary tract infection; VAP: ventilator associated pneumonia.

* Intervention period compared to combined control periods.

b All rates expressed per 1000 device/days.

4. Discussion

In this study evaluating the impact of using PPX-UVD for a 3 month period in a burn ICU, we found that PPX-UVD significantly reduced environmental bioburden, which notably did not include MDROs after routine housekeeping.

Numerous studies have demonstrated the contamination of hospital environmental surfaces by HAIs, pathogens, which can act directly as fomites for pathogen transmission or as a reservoir to contaminate hands of healthcare workers [22-24]. Epidemiologic studies have shown that patients hospitalized in rooms previously occupied by individuals infected or
Table 4 – Healthcare associated multidrug resistant organisms (MDRO) reported during 3 month control periods and trial of portable pulsed-xenon ultraviolet light disinfection (PPX-UVD).

<table>
<thead>
<tr>
<th>Occupied bed days (OBD)</th>
<th>Control: 1 year prior (per 1000 OBD)</th>
<th>Control: pre-PPX-UVD (per 1000 OBD)</th>
<th>Intervention: PPX-UVD (per 1000 OBD)</th>
<th>Control: post-PPX-UVD (per 1000 OBD)</th>
<th>p-Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Clostridium difficile</td>
<td>2 (2.1)</td>
<td>2 (3.0)</td>
<td>0 (0)</td>
<td>0 (0)</td>
<td>0.35</td>
</tr>
<tr>
<td>ESBLb</td>
<td>0 (0)</td>
<td>1 (1.5)</td>
<td>1 (1.5)</td>
<td>1 (1.7)</td>
<td>0.41</td>
</tr>
<tr>
<td>Enterobacteriaceae</td>
<td>1 (1.1)</td>
<td>0 (0)</td>
<td>0 (0)</td>
<td>1 (1.7)</td>
<td>0.35</td>
</tr>
<tr>
<td>MDRb Pseudomonas aeruginosa</td>
<td>6 (6.4)</td>
<td>1 (1.5)</td>
<td>3 (4.6)</td>
<td>1 (1.7)</td>
<td>0.25</td>
</tr>
<tr>
<td>MRSAb</td>
<td>1 (1.1)</td>
<td>1 (1.5)</td>
<td>3 (4.6)</td>
<td>2 (3.4)</td>
<td>0.15</td>
</tr>
<tr>
<td>Any MDRGb</td>
<td>10 (10.6)</td>
<td>5 (7.6)</td>
<td>7 (10.7)</td>
<td>5 (8.6)</td>
<td>0.72</td>
</tr>
<tr>
<td>Any MDR GNRb</td>
<td>2 (2.1)</td>
<td>2 (3.0)</td>
<td>4 (6.1)</td>
<td>4 (6.9)</td>
<td>0.17</td>
</tr>
</tbody>
</table>

* Intervention period compared to combined control periods.

b ESBL: extended spectrum beta lactamase; MDR: multidrug resistant; MRSA: meticillin-resistant Staphylococcus aureus; MDRO: multidrug resistant organism; GNR: gram negative rod.

Table 5 – Clinical bioburden (all positive clinical cultures) observed during 3 month control periods and trial of portable pulsed-xenon ultraviolet light disinfection (PPX-UVD).

<table>
<thead>
<tr>
<th>Occupied bed days (OBD)</th>
<th>Control: 1 year prior (per 1000 OBD)</th>
<th>Control: pre-PPX-UVD (per 1000 OBD)</th>
<th>Intervention: PPX-UVD (per 1000 OBD)</th>
<th>Control: post-PPX-UVD (per 1000 OBD)</th>
<th>p-Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>All bacteria</td>
<td>117 (123.9)</td>
<td>94 (142.2)</td>
<td>86 (131.7)</td>
<td>93 (160.1)</td>
<td>0.18</td>
</tr>
<tr>
<td>All GNRb</td>
<td>85 (90.0)</td>
<td>74 (112.0)</td>
<td>69 (105.7)</td>
<td>69 (118.8)</td>
<td>1.0</td>
</tr>
<tr>
<td>Any MDRGb</td>
<td>30 (31.8)</td>
<td>15 (22.7)</td>
<td>14 (21.4)</td>
<td>42 (72.3)</td>
<td>0.03</td>
</tr>
<tr>
<td>% MDRO/all bacteria</td>
<td>25.6</td>
<td>16.0</td>
<td>16.3</td>
<td>45.2</td>
<td>0.07</td>
</tr>
<tr>
<td>Any MDR GNRb</td>
<td>16 (16.9)</td>
<td>8 (12.1)</td>
<td>8 (12.3)</td>
<td>29 (49.9)</td>
<td>0.07</td>
</tr>
<tr>
<td>%MDR GNR/all GNR</td>
<td>18.9</td>
<td>10.8</td>
<td>11.6</td>
<td>42.0</td>
<td>0.08</td>
</tr>
<tr>
<td>Any GPb MDRO</td>
<td>14 (14.8)</td>
<td>5 (7.6)</td>
<td>5 (7.7)</td>
<td>9 (15.1)</td>
<td>0.10</td>
</tr>
<tr>
<td>% MDR GP/any GP</td>
<td>53.8</td>
<td>31.3</td>
<td>41.7</td>
<td>45.0</td>
<td>0.22</td>
</tr>
<tr>
<td>Any Clostridium difficile</td>
<td>3 (3.2)</td>
<td>3 (4.5)</td>
<td>1 (1.5)</td>
<td>0 (0)</td>
<td>0.34</td>
</tr>
</tbody>
</table>

* Intervention period compared to combined control periods.

b GNR: gram negative rod; MDRO: multidrug resistant organism; MDR: multidrug resistant; GP: gram positive.

colonized with MRSA, VRE, C. difficile, A. baumannii, or P. aeruginosa are at risk of MDRO acquisition from the shared environment [9]. Cleaning the environment to reduce this risk is critical, but manual cleaning is complex and there are numerous limitations [8]. In this evaluation, PPX-UVD was shown to significantly decrease bioburden on the combined endpoint of high-touch surfaces and air in a burn ICU environment compared to manual cleaning alone. This reduction was driven through reduction of skin commensals, as typical HAI pathogens and MDRO were not identified in the environment either before or after PPX-UVD. These reductions in overall bioburden are concordant with other in vitro evaluations of this technology, either from inoculated surfaces or high-touch hospital surfaces after routine patient occupation [15,16,25]. While no HAI pathogens or MDRO were identified in the environment before PPX-UVD, this is not dissimilar to published outbreaks where only a minority of surfaces are contaminated and to a previous evaluation at this institution where only 5% of surfaces grew GNR from occupied rooms before routine cleaning [10].

This evaluation was not primarily designed to detect a statistically significant reduction in device-associated HAI or incident HA-MDRO acquisition, and differences were not seen. However, evaluation of these secondary endpoints demonstrated a prolonged period without a case of HA-CDI in the unit, despite multiple introductions of CDI as demonstrated by
positive clinical specimens in the wash-in and intervention periods, and in the absence of a reintroduction during the post-intervention period. The microbiology methods used for bacterial culture from the environment would not support detection of *C. difficile*, so this apparent clinical reduction cannot be supported by microbiology data.

Despite recent evidence of reductions in a number of other HAIs, HA-CDI remains a serious problem and has become the most common etiologic agent of HAI in the United States [26]. A recent study estimated the number of HA-CDI cases in 2011 alone approached 300,000, resulted in over 61,000 recurrences, and caused over 27,000 deaths [27]. The scope and impact in burn patients, however, has not been well characterized. A 2011 evaluation from this institution revealed an incidence of 7.9/10,000 patient-days, which was lower than contemporaneous data from other units of the facility, and without apparent impact on morbidity or mortality [7]. The incidence in that study was also lower than that seen in the BICU during the control and pre-intervention periods of this evaluation, although detection methods changed in the interim from antigen detection tests to the more sensitive PCR. Another US-based single-center evaluation in 2002 reported a HA-CDI incidence of 7.2/1000 admissions, and a 2015 evaluation from Tehran noted an overall prevalence of 2.5/1000 admissions, with deaths attributed to comorbidities [28, 29]. The population of this burn ICU notably differs from the population of most other ICUs, in that patients tend to be younger, with few comorbidities [7]. Nevertheless, each episode has the potential for serious morbidity and mortality, and drives an estimated excess cost of $4.8 billion in US acute-care facilities, so this should remain a problem deserving of attention in the burn ICU [30]. Even if *C. difficile* is not the highest infection prevention priority in the burn ICU, the opportunity to greatly reduce or eliminate this as a potential complication is clearly attractive.

The correlation seen here between use of PPX-UVD and the reduction of HA-CDI is supported by the existing literature and is biologically plausible. Nerandzic et al. have demonstrated a reduction in positive cultures for *C. difficile* from hospital surfaces (by 77% in rooms that had not been cleaned, and by 58% in rooms that had already undergone terminal cleaning including use of bleach) after PPX-UVD, and evaluations of other UVC disinfection units have also demonstrated reductions of *C. difficile* from the environment, depending on organic load, inoculum size, and dose of UVC [31, 32]. A quasi-experimental clinical study reported a 53% reduction in the HA-CDI rate, with observed reductions in *C. difficile* associated deaths and colectomies [17]. It was noted that among the patients who did acquire HA-CDI after initiation of PPX-UVD, 73% had been placed in rooms that had not been treated with the device prior to their admission. A retrospective study in a community hospital demonstrated a 41% reduction in HA-CDI facility-wide, despite using the device outside the ICU only after discharges of patients known to the infected with *C. difficile* [19]. Another retrospective evaluation demonstrated a 17% reduction in HA-CDI after PPX-UVD initiation compared to prior, a significant difference despite missing approximately 25% of contact precautions discharges [33]. Recent data from the same group suggest a dose-response between percentage of room discharges treated with PPX-UVD and reductions in HA-CDI. Nagaraja et al. reported a 22% decrease in the rate of facility-wide HA-CDI despite an 18% increase in community-acquired cases during the first year of PPX-UVD use, driven predominantly by a 70% decrease in the adult ICU setting [18]. The use of the device was low throughout the facility, but significantly greater in the adult ICUs compared to other units. In our setting, where all rooms were single-bed, all patients on contact precautions, patient movement tightly controlled, and admission of patients with community-associated CDI infrequent, it is plausible that HA-CDI could be reduced at least to the extent seen in other non-burn ICUs. Data from our setting were not available on percentage of discharges where PPX-UVD was used, although the number of uses per week exceeded the average number of discharges (data not shown).

Limited published data are available relating UVC disinfection to reductions in GNR HAI pathogens. A study using inoculated surfaces with MDR *A. baumannii* demonstrated a 3–4 log10 reduction in inoculum [34]. An evaluation of inoculated surfaces with another PPX-UVD unit demonstrated >2 log10 reductions in *Escherichia coli* and *P. aeruginosa* [35]. One hospital-based study evaluated environmental cultures from rooms which had housed patients infected with HAI pathogens including *Acinetobacter* spp. This study included only 2 rooms (10 samples) from *Acinetobacter* spp. infected patients, and demonstrated a nonsignificant 1.16 log10 reduction in colony-forming units [25]. Clinical studies have focused on MRSA, VRE, and *C. difficile*, and data on UVC disinfection and GNR are extremely limited. Haas et al. noted a 19% decrease in HA MDR GNR rates during PPX-UVD use compared to prior; the proportion of this that represents colonization vs. infection is unknown [33]. Two recent evaluations of surgical site infections revealed reductions after use of PPX-UVD bundled with other interventions, but data on organisms were not provided [36, 37]. Unfortunately, whether PPX-UVD may reduce environmental bioburden, HAI, or incident patient colonization by MDR GNR in the burn unit remains unresolved. Follow-up studies primarily powered to detect differences in HAI and HA-MDRO rates should be conducted in this environment.

Our study has a number of strengths and limitations. Its quasi-experimental design is clearly less robust than a randomized trial, although use of control periods before (including a wash-in period), after, and in the same season a year prior add validity to the design. A clinical bioburden category was included in order to account for the “organism pressure” in the unit which might drive environmental contamination and HAI rates in either direction. Interpretations of this as a stand-alone category must be very limited, but suggest no increase in clinical cultures positive for MDRO, a possible decrease, and most importantly add to the understanding of community-associated CDI pressure in this unit. Microbiological sampling could have missed some high-touch surfaces, and these were selected based on those commonly referenced by other investigators and based on prior information from sampling this unit [10]. Contact plates are also challenging to use on irregularly shaped surfaces such as door handles. However, the same sampling methodology was used for both before- and after-PPX-UVD sampling. There were no HAI pathogens or MDROs isolated from the environment even before PPX-UVD use, which excluded the possibility of demonstrating a reduction afterward. No demographic
information on patients or severity of injuries was collected, although similar overall numbers of OBD particularly in the immediate pre- and post-intervention periods demonstrates a similar census, and utilization ratios of invasive devices were fairly consistent throughout, which speaks to similar acuity of illness. The most important limitation is the relatively short period of time for the intervention, which particularly limits the ability to exclude an effect on HAI and incident MDRO acquisition, or to demonstrate statistical significance for reductions in uncommon events like HAI.

5. Conclusions

This evaluation of PPX-UD in a BICU setting revealed reductions in bacterial burden on the combined endpoint of high-touch environmental surfaces and air compared to terminal cleaning alone. This was driven by reductions in skin commensals, as no MDRO or GNR responsible for HAI were isolated from the environment, even before PPX-UD. Statistically significant changes in clinical HAI and MDRO rates were not seen during this 3 month evaluation period compared to control periods, though the unit experienced a prolonged interval before the next HA-CDI case. Follow-up studies aimed primarily at detecting changes in HAI and MDRO rates in this setting, including GNR data, should be conducted.

Conflicts of interest

The authors endorse no conflicts of interest pertaining to the work described.

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Brief report

Utilization and impact of a pulsed-xenon ultraviolet room disinfection system and multidisciplinary care team on \textit{Clostridium difficile} in a long-term acute care facility

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Key Words:
Long-term care
No-touch disinfection
\textit{Clostridium difficile}
Multidisciplinary teams

Health care–associated transmission of \textit{Clostridium difficile} has been well documented in long-term acute care facilities. This article reports on 2 interventions aimed at reducing the transmission risk: multidisciplinary care teams and no-touch pulsed-xenon disinfection. \textit{C difficile} transmission rates were tracked over a 39-month period while these 2 interventions were implemented. After a baseline period of 1 year, multidisciplinary teams were implemented for an additional 1-year period with a focus on reducing \textit{C difficile} infection. During this time, transmission rates dropped 17\% ($P = .91$). In the following 15-month period, the multidisciplinary teams continued, and pulsed-xenon disinfection was added as an adjunct to manual cleaning of patient rooms and common areas. During this time, transmission rates dropped 57\% ($P = .02$). These results indicate that the combined use of multidisciplinary teams and pulsed-xenon disinfection can have a significant impact on \textit{C difficile} transmission rates in long-term care facilities.

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It has been repeatedly demonstrated in the literature that the health care environment suffers from widespread contamination and extended survival of multidrug-resistant organisms.\textsuperscript{1} A number of studies have linked this environmental contamination to an increased risk of health care–associated infections (HAIs).\textsuperscript{2,3} For example, a positive culture for \textit{Clostridium difficile} from a prior room occupant has been found to put the subsequent patient at 2.35 times greater risk of acquiring the same infection.\textsuperscript{4} Because there is no direct contact between the 2 patients, this prior room occupancy risk can be attributable to environmental acquisition.\textsuperscript{2}

Interventions to address HAIs in long-term acute care (LTAC) facilities have posed unique challenges for infection prevention, specifically in the area of enhanced environmental hygiene. Long-term care patients have more compromised immune function than traditional acute care patients and are more likely to be colonized with organisms such as \textit{C difficile}.\textsuperscript{6} Many hospitalized patients are transferred to and from LTAC facilities, increasing the likelihood of acquiring \textit{C difficile} infection in the process.\textsuperscript{7,8} Infected patients and asymptomatic carriers can shed pathogens onto environmental surfaces.\textsuperscript{9} If these surfaces are not properly disinfected, infection can be spread by direct contact or cross-contamination by health care workers. This is especially relevant with \textit{C difficile} infection, which is the leading cause of health care–associated diarrhea.\textsuperscript{10} This issue can be compounded in LTAC facilities, where the average length of stay is close to a month, and the communal design of the facilities enhances the interaction among patients.

As a result of the well-described link between environmental contamination and HAI acquisition, health care facilities are now exploring new methods of interrupting transmission. Many of these methods are based on the multidisciplinary approaches recommended in infection prevention best practice guidelines. An additional consideration has been enhancing the effectiveness of environmental disinfection. No-touch disinfection technologies have been developed as an adjunct to manual cleaning practices. The goal of these devices is to complete disinfection of surfaces that

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Conflicts of interest: Authors Simmons, Dale, Stibich, and Stachowiak are employees and shareholders of Xenex Disinfection Services, LLC.

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may have been missed by environmental cleaning staff. Such technologies use hydrogen peroxide vapor, pulsed-xenon ultraviolet light (PX-UV), or mercury ultraviolet light (UV). There are several outcome studies demonstrating reduced infection rates after the implementation of PX-UV, but this evidence has been isolated to acute care facilities.11-13 To our knowledge, no research exists to date that describes the use of no-touch disinfection in the LTAC setting.

The purpose of this study is to address the effectiveness of 2 hospital-associated (HA) *Clostridium difficile* prevention methods implemented over a 3-year period. First, the use of a multidisciplinary prevention team of health care workers dedicated to *Clostridium difficile* prevention was assessed. Subsequently, PX-UV was implemented as an enhanced disinfection measure.

**METHODS**

**Baseline infection prevention and surveillance**

This evaluation was conducted at an urban LTAC hospital in the Southeastern United States. Most patient rooms contain a single bed with a connected private bathroom. Per Centers for Disease Control and Prevention guidelines, facility policy required contact precautions and hand hygiene with soap and water when caring for patients with *Clostridium difficile*. After discharge, rooms and bathrooms are terminally cleaned with a sodium hypochlorite solution. *Clostridium difficile* infection rates were determined using the National Healthcare Safety Network’s infection surveillance reporting criteria. Institutional review board exemption was not sought because the research used existing data. During the 12-month preintervention period, no new infection prevention policies or protocols were implemented.

**Multidisciplinary team intervention**

A multidisciplinary *Clostridium difficile* prevention team was formed in March 2011 and was comprised of staff members from pharmacy, nursing, respiratory therapy, rehabilitation, dietary, laboratory, environmental services, building maintenance, and infectious disease. Before the formation of the prevention team, efforts to control the spread of *Clostridium difficile* infection included increasing the visibility of isolation signage using large and brightly colored signs, daily round to assess compliance with isolation practices, re-education for staff on the need for hand hygiene with soap and water when caring for *Clostridium difficile* patients, and implementation of disposable patient care equipment in isolation rooms (blood pressure cuffs, stethoscopes, and thermometers).

The multidisciplinary team reviewed available best practice guidelines for prevention of *Clostridium difficile* and implemented several new processes in June 2011. An initial measure recommended by the multidisciplinary team in September 2014, in addition to the performance improvement programs already implemented by the multidisciplinary team. The PX-UV device was used as a continuing multidisciplinary team approach. HA-Cdiff infection; PX-UV, pulsed-xenon ultraviolet light disinfection.

Finally, clinical staff were re-educated on the signs of *Clostridium difficile* infection to ensure that patients were identified and isolated in a timely manner.

**PX-UV device**

The PX-UV device (Xenex 426i; Xenex Disinfection Services, San Antonio, TX) uses a high-voltage discharge capacitor connected to a xenon flash lamp to release high-intensity, polychromatic pulses of UV light that cover the entire germicidal spectrum (210-280 nm). This novel technology differs from other sources of UV disinfection, which use low-pressure mercury lamps to produce monochromatic UV light.14 The implementation of these devices has been previously described.15 The devices are designed to deliver UV light to surfaces throughout the room, with a specific focus on high-touch surfaces. Multiple disinfection positions are used to assure that surfaces are not shadowed from the light. Information about each disinfection cycle is logged by the device and uploaded to an online portal. These data are used to assure that housekeeping staff are placing the robot in the appropriate number of positions for the area they are disinfecting and to track the overall usage within the health care facility.

**PX-UV adjunct**

One PX-UV device was deployed between July 2012 and September 2014, in addition to the performance improvement programs already implemented by the multidisciplinary team. The PX-UV device was used specifically as an adjunct to standard manual cleaning of patient areas. The usage goal across the LTAC facility included all patient rooms after discharge and communal living areas on a weekly basis, such as dining rooms, rehabilitation areas, and lounges. Device usage was tracked using an on-board data log. On average, the PX-UV device was used to disinfect 85 discharge rooms and communal living areas per month. Disinfection was primarily done in the communal living areas because of the low discharge volume at the facility.

**Statistical analysis**

HA *Clostridium difficile* infection rates for each intervention were compared with infection rates of the directly previous intervention period. Because of the nonparametric nature of our data, comparisons were made using a 2-sample Wilcoxon rank-sum test in Stata.
software version 12.1 (StataCorp, College Station, TX). The analysis was sufficiently powered to detect differences between the intervention groups.

RESULTS

During the 12-month preintervention period, the HA C difficile infection rate was 23.3 per 10,000 patient days. On the addition of the multidisciplinary team, the HA C difficile infection rate dropped 17.3% to 19.3 per 10,000 patient days (P = .91). PX-UV was then implemented in July 2012 while the multidisciplinary team approach continued (Fig 1). Over a 15-month period, infection rates dropped 56.9% compared with the baseline year to 8.3 per 10,000 patient days (P = .02) (Table 1). Based on these outcomes, it is predicted that the facility was able to prevent 29 HA C difficile infections and generate over 210 additional patient bed days within the 15-month intervention. At $13,500 in hospital care costs per case, this could have potentially resulted in net savings of approximately $300,000.16–23

DISCUSSION

HA C difficile rates during the use of PX-UV in conjunction with the multidisciplinary team were lower than those rates during the multidisciplinary team intervention alone. Based on the available data, it is not possible to determine whether this impact is solely from the addition of PX-UV or from a synergistic effect of the 2 interventions.

The use of PX-UV in the LTAC setting is very different from the applications that have previously been reported in acute care settings. Patients are discharged much less frequently from LTAC facilities; therefore, there is less daily demand for PX-UV for terminal cleaning purposes. Rather, PX-UV was used in high-traffic ancillary and communal living areas. These areas provide an environment where health care workers and patients regularly intermingle, and there are frequent opportunities for environmental contamination and transmission. These data show the potential of enhanced disinfection for impacting the rates of C difficile in LTAC facilities and other facilities with different operational patterns than acute care hospitals.

These findings further support the previous research implicating the environment as a factor in the transmission of C difficile. Colonized and infected C difficile patients will shed large numbers of bacteria into the environment, and these bacteria can persist for months. Because of extended length of stay, lower immune function of patients, and the communal nature of long-term care, it is reasonable to expect that the exposure risk to C difficile from the environment is substantial in this care setting. While these results demonstrate that no-touch disinfection could be successfully implemented a single LTAC, more studies are needed to demonstrate that this type of program can be replicated in other LTACs. It may be useful for future research to perform environmental sampling of the patient rooms and communal areas of LTAC facilities to validate the assumption that the communal areas serve as an important reservoir in this care setting.

This study is inherently limited by the quasi-experimental design. The nonrandomized design limits the ability to attribute the reduction in HA C difficile solely to the implementation of the PX-UV device. However, these results are corroborated by previous quasi-experimental studies showing reductions in infections after the implementation of PX-UV. This research adds to the body of evidence describing the effectiveness of PX-UV devices and demonstrates that this technology can be successfully implemented in the long-term care setting.

References


Using Pulsed Xenon Ultraviolet to Decrease Contamination in Operating Rooms During Terminal Cleaning

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Abstract

Introduction

• Per AORN guidelines, operating rooms should be terminally cleaned every 24 hours. This cleaning is necessary to reduce the microbial burden on the environment in operating rooms.1
• Studies have shown that only 47% of operating room surfaces are cleaned throughout the day.2 Pathogens such as MRSA, Acinetobacter spp., Pseudomonas spp. and E. coli can be recovered from OR surfaces after cleaning.2,3
• Pulsed Xenon has been used to enhance environmental cleaning in patient rooms, and may be useful to terminally clean operating rooms.4,5

Objective

• The purpose of this study was to compare the contamination levels after standard terminal cleaning with a modified Turnover Clean + PX-UV.

Methods

• Environmental samples were taken from five surfaces in 16 ORs after standard terminal cleaning, and from the same five surfaces in 22 ORs after Turnover Clean + PX-UV.
• Turnover Cleaning + PX-UV consisted of a standard between case clean, plus removal of visible soil. There was no routine disinfection of surfaces that did not have visible soil. After cleaning, the PX-UV device was run for 5 minutes in two different positions.
• The surfaces selected for sampling were the top and bottom of the anesthesia cart, the OR light, the OR table, and the floor.
• Samples were taken using contact plates (Hardy Diagnostics P34). Samples were collected, incubated and read per the manufacturers instructions.
• The data was analyzed using negative binomial regression.

Sample Site Selection

Samples were taken from: 1. The anesthesia cart, center top. 2. The anesthesia cart, outside center of the bottom drawer. 3. The operating room light, halfway between the center point and the edge on the top surface. 4. The turnstile, top center. 5. The floor, within a 4 foot radius of the operating table.

Introduction

Table 1: Comparison of Heterotrophic plate counts, According to Room Cleaning Status

<table>
<thead>
<tr>
<th>Disinfection</th>
<th>Number of Samples</th>
<th>Mean</th>
<th>Median</th>
<th>IQR</th>
<th>Min</th>
<th>Max</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Standard Terminal Clean</td>
<td>78</td>
<td>2.73</td>
<td>1.50</td>
<td>1.47</td>
<td>0.00</td>
<td>17</td>
<td>0.001</td>
</tr>
<tr>
<td>Turnover Clean + PX-UV</td>
<td>110</td>
<td>1.05</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>19</td>
<td>0.001</td>
</tr>
</tbody>
</table>

Table 2: Comparison of Contamination Levels of Different Surfaces, According to Room Cleaning Status

<table>
<thead>
<tr>
<th>Room Surface</th>
<th>Cleaning Method</th>
<th>Number of Samples</th>
<th>Mean HPC</th>
<th>% reduction</th>
</tr>
</thead>
<tbody>
<tr>
<td>Anesthesia Cart Top</td>
<td>Standard Clean</td>
<td>15</td>
<td>4.27</td>
<td>46.5%</td>
</tr>
<tr>
<td></td>
<td>Quick Clean + PX-UV</td>
<td>15</td>
<td>2.06</td>
<td>53.5%</td>
</tr>
<tr>
<td>Anesthesia Cart Bottom</td>
<td>Standard Clean</td>
<td>15</td>
<td>2.73</td>
<td>57.5%</td>
</tr>
<tr>
<td></td>
<td>Quick Clean + PX-UV</td>
<td>15</td>
<td>1.60</td>
<td>67.0%</td>
</tr>
<tr>
<td>OR Light</td>
<td>Standard Clean</td>
<td>15</td>
<td>2.73</td>
<td>57.5%</td>
</tr>
<tr>
<td></td>
<td>Quick Clean + PX-UV</td>
<td>15</td>
<td>1.60</td>
<td>67.0%</td>
</tr>
<tr>
<td>OR Table</td>
<td>Standard Clean</td>
<td>15</td>
<td>2.06</td>
<td>53.5%</td>
</tr>
<tr>
<td></td>
<td>Quick Clean + PX-UV</td>
<td>15</td>
<td>1.60</td>
<td>67.0%</td>
</tr>
<tr>
<td>Floor</td>
<td>Standard Clean</td>
<td>16</td>
<td>5.75</td>
<td>84.2%</td>
</tr>
<tr>
<td></td>
<td>Quick Clean + PX-UV</td>
<td>16</td>
<td>3.45</td>
<td>84.2%</td>
</tr>
</tbody>
</table>

Results

• A total of 188 samples were analyzed with two samples missing because of laboratory error.
• In the terminal cleaning arm of the study, the mean plate count was 2.73 colony forming units (CFU) per sample.
• In the Turnover Clean+PX-UV arm, the mean plate count was 1.05 CFU per sample.
• The bacterial contamination levels were significantly lower in the rooms that received a turnaround clean+PX-UV (p<0.001).

Conclusions

• The Turnover Clean+PX-UV method was shown to be superior to standard terminal cleaning. Turnover Clean + PX-UV is a promising alternative to standard terminal cleaning methods. Additional research is warranted to verify these results.

References

Introduction

Hospital-acquired infections (HAIs) are a leading cause of mortality and morbidity, and cost to healthcare systems. The cumulative incidence of HAIs following various surgical procedures on the African continent ranges from 10–31%, markedly higher than that in high-income countries.1 Increasingly, antimicrobial resistant organisms are being seen in the hospital setting. A portion of these infections can be attributed to the environment, as many common hospital pathogens can survive for weeks to months in the patient care environment.2 The inability of manual cleaning to effectively disinfect patient care areas has been demonstrated in studies in the USA setting.3

Ultraviolet (UV) room disinfection is becoming more common in hospitals. Over 300 hospitals in the USA alone use pulsed xenon (PX) ultraviolet (PX-UV) devices for infection control purposes, and these have been linked to a reduction in HAI rates of more than 50%.4–10 However, independent laboratory data on the germicidal impact of PX-UV on resistant bacteria, bacterial spores, fungi, viruses and the Ebola virus are lacking in the literature. Laboratory data are presented in this paper on the log reductions observed after the exposure of PX-UV to a variety of organisms in a laboratory setting.

Method

Testing for all organisms, except the Ebola virus and Bacillus anthracis, was conducted at the National Center for Biotechnology, part of the Spanish National Research Council (Consejo Superior de Investigaciones Científicas), the largest public research institute in Spain. The Eboba virus and B. anthracis, testing was conducted at the Texas Biomedical Research Institute, which contains a full suit Biosafety Level 4 (BSL-4) laboratory, with clearance from the US Centers for Disease Control and Prevention (CDC) with respect to handling a range of BSL-4 agents, including the Ebola virus.

Pulsed xenon ultraviolet device

The PX-UV device, a patented device which produces high-intensity germicidal light using a pulsing xenon lamp, and which is fully commercialised for use in hospital and other settings, was used as a source in all of the tests. The PX-UV device has been described in detail elsewhere in the literature.11

Laboratory methods

A separate section for each pathogen or group of pathogens is provided.

Gram-negative and gram-positive bacteria and fungi

Isolates of the following organisms were obtained by donation from hospital networks in Spain:

- Extended-spectrum beta lactamase-producing Klebsiella pneumoniae.
- Pseudomonas aeruginosa, which produces carbapenemase.
- Acinetobacter baumannii resistant to antibiotics.
- Escherichia coli carbapenemase.
- Methicillin-resistant Staphylococcus aureus.
- Aspergillus niger.

Prior culture and growth of the bacteria and fungus was carried out in a Luria broth liquid culture medium at 37 °C until concentration ranges of $10^6$–$10^7$ colony-forming units (CFUs) per milliliter were obtained, depending on the type of organism. The suspensions obtained were diluted in saline solution, and subsequently agitated to ensure their homogeneity, then placed in empty p-100 Petri dishes. The inocula were spread with sterile glass-inoculating loops. The inocula were then allowed to dry.
at ambient temperatures under the sterile laminar flow of the biosafety cabinet.

Two control Petri dishes and two Petri dishes treated in identical conditions were prepared for each organism, and placed on a mount at an angle of 45 degrees from horizontal, at approximately one metre in height, and at a distance of one metre from the PX-UV device. The exposure time was five minutes. The control Petri dishes remained covered and the treated ones remained open during exposure. A curve of exposure times was carried out at 0, 5, 10, 15 and 30 minutes for A. niger. Each exposure time was performed in triplicate.

After exposure, the control and treated Petri dishes were incubated at 37 °C for 24–72 hours, depending on the degree of growth of the colonies. The results were obtained by comparing the number of colonies in the treated and control samples.

The protocol was repeated on three different days, on three different degrees of culture growth, i.e. in biological triplicate. Therefore, there were six final figures for the treated and control samples.

**Gram-positive bacterial spores**

The following Gram-positive bacterial spores were used from commercially available sources:

- **Geobacillus stearothermophilus** ProSpore® spore kit (10⁶ spores), in 4 ml ampoules with culture medium and growth indicator.
- **B. atrophaeus** spore kit (10⁷/ml), in a 10 ml vial, with culture medium and growth indicator.

The preparations of G. stearothermophilus and B. atrophaeus were carried out by adding an inoculum of 1 x 10⁶ to 5 x 10⁶ spores to each empty p-100 Petri dish. The inocula were allowed to dry at an ambient temperature inside the biosafety cabinet under the flow of sterile laminar air for 1–2 hours. The inocula were spread in the central area of each Petri dish, using a sterile glass-inoculating loop in order to facilitate drying.

A pair of control Petri dishes and a pair of treated Petri dishes were prepared under identical conditions for each bacteria. Bacteria were exposed to PX-UV in the same manner as that previously described. After exposure to UV light, replications of the treated and control Petri dishes were carried out using RODAC®-type contact plates, prepared with tryptic soy agar culture medium. The RODAC® plates were incubated at 37 °C for 24–72 hours, depending on the degree of growth of the colonies. The results were obtained by comparing the number of colonies in the treated and control samples. The protocol was repeated four times in order to obtain the final data.

**Bacillus anthracis**

A similar experiment was performed with live B. anthracis spores. Care was taken to ensure that all bacteria were in the hard-to-kill spore form. PX-UV exposure times were 15, 30, 45 and 60 minutes at a distance of one metre and a height of one metre.

**Middle East respiratory syndrome coronavirus**

Viral suspensions, with an approximate titre of between 10⁵ and 10⁶ CFU/ml, were prepared in a Dulbecco’s modified eagle medium (DMEM) culture, supplemented with 5% foetal bovine serum (FBS). The viral suspensions were applied in the form of a small drop of 500 μi in the centre of p-100 Petri dishes which had previously been prepared by applying a sheet of Parafilm® plastic film in order to reduce the surface tension of the drop so that it remained more exposed. Further optimisation was created in a follow-up experiment by replacing the 500 μi drop with 20 drops of 5 μi per Petri dish in order to reduce the shielding from the UV light produced by the liquid in the sample.

The exposure conditions were similar to those already described for the bacteria, with the exception that the liquid suspensions were placed directly on the working surface of the biosafety cabinet. A pair of control Petri dishes and a pair of treated Petri dishes were prepared under identical conditions for each exposure. After carrying out exposure to UV light, titration of the control and treated viral suspensions was performed, and their infectivity assessed in susceptible Vero E6 (African green monkey) cells through tests for the formation of lysis plaques. The viral titres in the samples were treated for differing periods and to determine the reduction in viral viability that exposure to PX-UV produced in Middle East respiratory syndrome coronavirus (MERS-CoV). The aforementioned protocol was repeated on the basis of three different prior growths of cultures, i.e. in biological triplicate.

**Vaccinia virus and infectious bursal disease virus**

An identical protocol to that described for the MERS-CoV virus was applied to the procedure carried out for vaccinia virus and infectious bursal disease virus (IBDV). The growth and titration of the vaccinia virus was performed through the experimental infection of susceptible BSC-40 cells of the *Cercopithecus aethiops* primate. The growth and titration of IBDV was performed by using the QM7 cellular line, derived from a fibrosarcoma in the Japanese quail (*Coturnix japonica*).

The only difference from the previously described protocol was that initially 100 μi drops were prepared for the IBDV virus, instead of 500 μi. An attempt was made to optimise the protocol for both viruses by reducing the volume of the samples to 5 μi droplets. Three tests for each virus were performed, each of these consisting of two control Petri dishes and two treated ones.

**Vesicular stomatitis virus**

The growth and titration of the vesicular stomatitis virus (VSV) was performed through the experimental infection of susceptible BSC-40 cells of the *C. aethiops* primate. The cultures were prepared and kept in a liquid DMEM medium, supplemented with 10% FBS. Infection of the cells in the DMEM medium was then performed, and they were subsequently kept in the DMEM medium with 2% FBS. The viral suspensions obtained in the DMEM medium with 2% FBS had a titre of approximately 10⁶ lysis plaque-forming units (PFUs) per millilitre. These suspensions...
were agitated to ensure their homogeneity, and inoculated into p-100 Petri dishes. The inoculum was spread with the inoculating loops. Thus, the prepared Petri dishes were allowed to dry under the sterile laminar flow of the biosafety cabinet at an ambient temperature for approximately 30 minutes. PX-UV exposure was performed using the same curve of times, and under identical conditions to those used for A. niger. Post-exposure viral control and treatment samples were recovered, and treated with the addition of DMEM culture with 2% FBS to each Petri dish. The infectivity of each sample was then assessed in susceptible BSC-40 cells through lysis plaque-formation tests. The viral titres were expressed in PFUs/ml.

Live Ebola virus

To test the antiviral affects of PX-UV exposure on the Ebola virus, 20 μi of virus was dried onto a chamber slide. After drying, the samples were positioned vertically at a distance of one metre, and exposed to UV light generated by the Xenex® robot for various lengths of time, i.e. 1, 2, 5 and 10 minutes. The virus was resuspended and harvested from the slide, and the remaining infectious virus was quantified by plaque assay.

Results

The study’s independent laboratory testing results, involving PX-UV, are detailed in Table 1.

<table>
<thead>
<tr>
<th>Organism</th>
<th>Cycle time (minutes)</th>
<th>Distance (metres)</th>
<th>Pathogen count before disinfection</th>
<th>Pathogen count after disinfection</th>
<th>Logarithmic reduction measured</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Klebsiella pneumoniae</em></td>
<td>5</td>
<td>1</td>
<td>1.88E+10</td>
<td>3.42E+01</td>
<td>8.74</td>
</tr>
<tr>
<td><em>Pseudomonas aeruginosa</em></td>
<td>5</td>
<td>1</td>
<td>9.12E+10</td>
<td>4.30E+01</td>
<td>9.33</td>
</tr>
<tr>
<td><em>Acinetobacter baumannii</em></td>
<td>5</td>
<td>1</td>
<td>6.07E+10</td>
<td>4.67E+01</td>
<td>9.11</td>
</tr>
<tr>
<td><em>Escherichia coli</em></td>
<td>5</td>
<td>1</td>
<td>3.32E+10</td>
<td>2.68E+01</td>
<td>9.09</td>
</tr>
<tr>
<td><em>Staphylococcus aureus</em></td>
<td>5</td>
<td>1</td>
<td>4.52E+10</td>
<td>3.47E+01</td>
<td>9.11</td>
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<tr>
<td><em>Geobacillus stearothermophilus</em></td>
<td>5</td>
<td>1</td>
<td>1.69E+06</td>
<td>2.57E+02</td>
<td>3.82</td>
</tr>
<tr>
<td><em>Bacillus atrophaeus</em></td>
<td>5</td>
<td>1</td>
<td>4.89E+05</td>
<td>2.51E+02</td>
<td>3.29</td>
</tr>
<tr>
<td><em>Aspergillus niger</em></td>
<td>10</td>
<td>1</td>
<td>1.07E+03</td>
<td>1.37E+02</td>
<td>0.89</td>
</tr>
<tr>
<td><em>Aspergillus niger</em></td>
<td>15</td>
<td>1</td>
<td>1.07E+03</td>
<td>6.03E+01</td>
<td>1.25</td>
</tr>
<tr>
<td><em>Aspergillus niger</em></td>
<td>30</td>
<td>1</td>
<td>1.07E+03</td>
<td>4.10E+01</td>
<td>1.61</td>
</tr>
<tr>
<td>MERS-CoV (liquid)</td>
<td>5</td>
<td>1</td>
<td>4.13E+04</td>
<td>2.17E+04</td>
<td>1.54</td>
</tr>
<tr>
<td>Vaccinia virus (liquid)</td>
<td>5</td>
<td>1</td>
<td>4.98E+06</td>
<td>1.63E+05</td>
<td>1.38</td>
</tr>
<tr>
<td>IBDV (liquid)</td>
<td>5</td>
<td>1</td>
<td>2.41E+07</td>
<td>3.33E+06</td>
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<td>VSV (dried)</td>
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<td>2.60E+05</td>
<td>0.00E+00</td>
<td>All</td>
</tr>
<tr>
<td><em>Bacillus anthracis</em></td>
<td>15</td>
<td>1</td>
<td>4.5E+03</td>
<td>0.00E+00</td>
<td>All</td>
</tr>
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<td>Ebola virus</td>
<td>1</td>
<td>1</td>
<td>1.85E+07</td>
<td>0.00E+00</td>
<td>All</td>
</tr>
</tbody>
</table>

IBDV: infectious bursal disease virus, MERS-CoV: Middle East respiratory syndrome coronavirus, VSV: vesicular stomatitis virus

Bacterial spores

Log reductions ranging from 3.29–3.82 CFUs/ml were observed for bacterial spores after five minutes of PX-UV exposure at one metre.

Bacillus anthracis

Growth was not observed for *B. anthracis* (detect threshold of a 3 CFU/ml log reduction) after 15 minutes of PX-UV exposure at one metre.

Fungi

Log reductions ranging from 0.33–1.61 CFUs/ml for fungi were observed after 5, 10, 15, and 30 minutes of exposure to PX-UV at one metre.

Viruses

Log reductions ranging from 0.86–1.54 PFUs/ml were observed when the inocula was in liquid form, and log reductions of ≥ 5.00 were observed for the dried virus after five minutes of PX-UV exposure at one metre.

Ebola virus

Growth was not observed (detection threshold of a 4 PFUs/ml log reduction) for the live Ebola virus after one minute of PX-UV exposure at one metre.

Discussion

There is a contamination level of ≤ 500 organisms/cm² in a typical hospital environment after cleaning. The level of disinfection for vegetative spores in a five-minute cycle achieved using...
the PX-UV device (8.7–9.1 log reduction) exceeds that which is necessary in the hospital environment. While the disinfection achieved was lower for the spore-forming organisms (3.29–3.82), it still exceeded the likely level of contamination in a hospital and patient care environment.

Additional time was required for disinfection of the fungus, *A. niger*, in order to reach a level of 1.61 CFU/ml log reduction at 30 minutes. *A. niger* is more resistant to UV light than vegetative organisms as it is a multicellular eukaryotic microbe, so these results were not unexpected.

Logarithmic reductions achieved for MERS-CoV, the vaccinia vaccinia virus and IBDV, were 0.58, 1.66 and 1.21 PFUs/ml, respectively. This lower reduction can be explained by the liquid nature of the virus preparations, which necessitated placing them horizontally on the surface for more indirect exposure, as well as the potential UV shielding caused by the viral suspension itself. To address these confounders, VSV was used as a virus sample which could be dried on a surface for an extended period and still retain its infectivity. This allowed the samples to be placed at 45 degrees for more direct exposure. Complete elimination of any detectable virus was noted in this case. It should be noted that viral contaminants would be in the dry form in most environmental situations in which PX-UV would be used.

The tests demonstrated that there was total elimination of the organisms at one and 15 minutes, respectively, for both the live Ebola virus and the *B. anthracis*. This indicates the potential of the PX-UV system to be deployed in an outbreak or biopreparedness manner.

The tests used here demonstrate the influence of laboratory methods over the reported effectiveness of technologies. For example, a large difference between wet and dry viral inocula was noted. A number of variables have been reported to influence the laboratory results in other research, including humidity, temperature, the smoothness of surfaces, protein loading, reflectivity, distance and other variables. While proof-of-concept data have been demonstrated in laboratory studies, readers are encouraged to seek data on the impact of a technology, such as PX-UV, in a real-world setting.

Lastly, the organisms chosen for these tests represent organisms which were causing, or which would have the potential to cause, significant public health threats, including extended-spectrum beta lactamase-producing organisms, carbapenemase-producing organisms, resistant strains of *A. baumannii* and *S. aureus*, the Ebola virus and *B. anthracis*. The magnitude of the log reduction observed from the use of PX-UV against each of these organisms indicated that PX-UV disinfection played a role in preventing transmission of these organisms, and thereby in reducing the associated morbidity and mortality. Furthermore, by decreasing the probability of transmission of these organisms through a contaminated environment, PX-UV can contribute to efforts to address antimicrobial resistance by reducing the number of infections, and therefore extending the effectiveness of antibiotics by reducing demand for them.

**Declaration**

Funding for testing at the National Center for Biotechnology was provided by a third party, while funding for testing at the Texas Biomedical Research Institute was provided by the manufacturer of the PX-UV device (Xenex Disinfection Services, San Antonio, USA).

**References**

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Evaluation of a pulsed-xenon ultraviolet room disinfection device for impact on contamination levels of methicillin-resistant *Staphylococcus aureus*

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**Abstract**

**Background**

Healthcare-acquired infections with methicillin-resistant *Staphylococcus aureus* (MRSA) are a significant cause of increased mortality, morbidity and additional health care costs in United States. Surface decontamination technologies that utilize pulsed xenon ultraviolet light (PPX-UV) may be effective at reducing microbial burden. The purpose of this study was to compare standard manual room-cleaning to PPX-UV disinfection technology for MRSA and bacterial heterotrophic plate counts (HPC) on high-touch surfaces in patient rooms.

**Methods**

Rooms vacated by patients that had a MRSA-positive polymerase chain reaction or culture during the current hospitalization and at least a 2-day stay were studied. 20 rooms were then treated according to one of two protocols: standard manual cleaning or PPX-UV. This study evaluated the reduction of MRSA and HPC taken from five high-touch surfaces in rooms...
vacated by MRSA-positive patients, as a function of cleaning by standard manual methods vs a PPX-UV area disinfection device.

**Results**

Colony counts in 20 rooms (10 per arm) prior to cleaning varied by cleaning protocol: for HPC, manual (mean = 255, median = 278, q1-q3 132–304) vs PPX-UV (mean = 449, median = 365, q1-q3 332–530), and for MRSA, manual (mean = 127; median = 28.5; q1-q3 8–143) vs PPX-UV (mean = 108; median = 123; q1-q3 14–183). PPX-UV was superior to manual cleaning for MRSA (adjusted incident rate ratio [IRR] = 7; 95% CI <1-41) and for HPC (IRR = 13; 95% CI 4–48).

**Conclusion**

PPX-UV technology appears to be superior to manual cleaning alone for MRSA and HPC. Incorporating 15 minutes of PPX-UV exposure time to current hospital room cleaning practice can improve the overall cleanliness of patient rooms with respect to selected microorganisms.

**Keywords**

MRSA, Methicillin-resistant Staphylococcus aureus, No touch disinfection, Pulsed Xenon Ultraviolet disinfection device, nosocomial infections

**Background**

Healthcare-acquired infection (HAI) with methicillin-resistant *Staphylococcus aureus* (MRSA) is a significant cause of mortality and morbidity in the United States accounting for up to $9.7 billion annually in additional health care costs, and €44.0 million annually in Europe [1,2]. In the Americas, Europe, and parts of Africa and Asia, MRSA is the predominant multi-drug resistant microbe, making it a global concern of escalating importance in terms of cost and patient safety [3]. Combating MRSA with new pharmaceutical agents offers only short-term solutions; unconventional approaches may comprise a more effective solution to drug-resistant infectious microbes [4].

Patients admitted to rooms vacated by MRSA-positive patients have higher relative risk of acquiring MRSA [5,6]. In a 2009 review of environmental cleaning studies, Dancer concluded that high-touch surfaces present one of the biggest risks of MRSA acquisition for patients, providing a source of direct infection to patients and of indirect infection via healthcare workers [7]. Decontaminating high-touch surfaces could prevent HAI [8]. Manual cleaning with approved disinfectants is the current standard of disinfection in most countries including the United States, and this requires supervision with constant reinforcement and education of environmental management service (EMS) staff to maintain effectiveness [9].

Surface decontamination technologies that utilize ultraviolet light or hydrogen peroxide may be effective at reducing microbial burden, possibly with greater consistency than is achieved with manual methods [10-13]. Portable pulsed xenon ultraviolet (PPX-UV) technology uses high-intensity broad-spectrum UV irradiation in the 200–320 nm range. UV breaks the
molecular bonds in DNA, thereby destroying the organism and spores in laboratory settings [12,14]. Spores from *Clostridium difficile* (c.diff) are killed by 185–230 nm UV irradiation, overlapping the range of the PPX-UV [15].

The efficacy of PPX-UV in hospitals in comparison to manual cleaning has not been demonstrated. The purpose of this study was to compare standard manual room-cleaning to PPX-UV disinfection technology for MRSA and bacterial heterotrophic plate counts (HPC) on high-touch surfaces in patient rooms.

**PPX-UV device**

We used a portable PPX-UV device (Xenex Healthcare Services, San Antonio, TX) measuring 30 L x 20 W x 38H inches (Figure 1). The device is used in empty patient rooms after discharge as prolonged exposure to UV can skin and eye irritation. The device used in this study housed a bulb twice as intense as in the device described by Stibich and colleagues [10], and it had new features such as a data logger, reflector, and UV pass filter. The data log recorded room number, user ID, time, date, number of pulses, amount of energy emitted and any error codes. The reflector was mounted on a column housing the xenon gas bulb emitting the pulsed UV rays. While column moved up and down during a 5-minute cycle, the reflector optimized the UV rays downward to high-touch surfaces. A UV pass filter blocked visible light while allowing UV-C to pass, making it less disturbing to the naked eyes when PPX-UV runs behind glass without curtains. UV is less effective in areas that are out of the direct line of sight; hence separate cycles for each area are recommended with 2 cycles around the patient's bed. In a typical patient room with living room and separate bathroom, a 5-minute cycle in three different positions is recommended plus 2–3 minutes for positioning for a total of 18 minutes per room (Figure 2). The device emitted ~450 flashes/cycle. The device requires positioning prior to each 5-minute cycle, so that it is necessary to have an operator in the vicinity. The device was easy to set up and operate per EMS staff operating it.

**Figure 1 Photograph of the PPX-UV device.**

**Figure 2 Schematic of two patient rooms showing positioning of PPX-UV unit.**

**Methods**

This comparative study was conducted January-February 2012 in the Central Texas Veterans Health Care System, Temple, TX with approval from its institutional review board. We are a 120-bed acute care hospital. In the facility studied, all patients undergo nasal swab at admission, transfer and discharge; these samples are tested for MRSA by polymerase chain reaction (PCR) (at admission) or culture (transfer/discharge) as a routine process of care according to institutional policy. Patients with MRSA infection either community acquired or hospital acquired are identified by culturing suspicious body site or body fluids. Individuals with MRSA detected by PCR or culture or with prior-year positive PCR/culture are placed on contact isolation during their entire hospitalization. We studied rooms vacated by patients that had a MRSA-positive PCR or culture during the current hospitalization and at least a 2-day stay.

Samples from five high-touch surfaces (bedrail, toilet seat, bathroom handrail, call button, tray table) were collected using Rodac plates, before terminal cleaning of rooms vacated by a
patient on isolation for MRSA. For non-flat surfaces such as handrail, contact plates were rolled so that the entire surface was contacted. The rooms were then treated according to one of two protocols: standard manual cleaning or PPX-UV.

In the first group (manual arm; n = 10), rooms were cleaned using the standard procedures. Standard manual cleaning included cleaning visible dirt then soak and-wipe cleaning with Dispatch® (The Clorox Company, Oakland, CA) disinfection solution. Dispatch® is a pre-mixed, ready-to-use 1:10 bleach solution with a contact time of 1 minute for killing bacteria. EMS personnel used cotton rags soaked in this pre-mixed solution with one to two applications and passes for all areas and surfaces in a patient room regardless of soiling. On an average, EMS personnel used 3–4 rags per room. These multiuse rags were then laundered for later use in another room. This included all the walls in bathroom and living room up to head height. EMS personnel replaced curtains if present.

In the second group (PPX-UV arm; n = 10), the room was pre-cleaned using same process described in the manual arm using Dispatch® except the focus was to clean only the visibly soiled surfaces instead of every surface in the room to achieve an aesthetic clean vs the thorough cleansing of the manual arm thus saving valuable turn-around time. Then the PPX-UV device was deployed according to manufacturer's protocol. We then collected our post-cleaning samples ensuring that Dispatch® had completely dried of the sampling surface. Finally, the PPX-UV rooms were cleaned manually per standard protocol (similar to manual arm) to meet requirements for the healthcare facility.

Post-cleaning samples were taken from surface locations immediately adjacent to the pre-cleaning sample locations. In the PPX-UV arm the sampling took place immediately after completion of the PPX-UV cycles for the room. The Rodac sample plates were transported on icepack-lined shipping containers by overnight courier to Antimicrobial Test Laboratories (ATL), an independently contracted microbiology laboratory in nearby Round Rock, Texas. Available rooms were included if they met study criteria (MRSA-positive patient vacating; sufficient time for shipping that day); they were randomly assigned to either manual or PPX-UV arm. In order to ensure next-day delivery, no samples were collected after the final shipper’s pick-up time of 7 pm. The microbiologist at ATL was blinded to protocol arm. EMS personnel were aware of the fact that samples were being collected pre- and post-cleaning but were not aware of specific surfaces from which samples were being collected.

Environmental testing procedure

TSA supplemented with Lecithin and Tween 80 (neutralizes bleach) and HardyCHROM MRSA Rodac contact plates (Hardy Diagnostics, Santa Maria, CA) were received at ATL approximately 18–24 hours after sampling. All samples were given specific identification numbers prior to incubation. HPC and MRSA contact plates were incubated for 48 ± 4 hours at 30 ± 2°C and 36 ± 1°C, respectively, and individual colonies counted immediately after incubation. Every colony, regardless of color or morphology, was recorded for HPC counts. The target organism MRSA was morphologically identified (deep pink to magenta-colored colonies), and regardless of size, were recorded for MRSA counts per package insert from Hardy Diagnostics. Further MRSA colonies were then subcultured and identified using standard microbiological methods. Contact plates resulting in confluent growth were designated as too numerous to count (TNTC) for reporting purposes. TNTC and any plates with a colony count of 250 or higher for MRSA or HPC were assigned a value of 250 colonies.
Measures and analysis

We assessed counts of MRSA and HPC for each of 20 rooms, summing samples taken from the five different surfaces to create total MRSA and total HPC counts, respectively, for pre- and post-cleaning measures (four variables in all). Additional measures were individual surface counts, surface type, microbe type (HPC; MRSA), cleaning time in minutes, and room size in square meters. The independent variable of primary interest was cleaning protocol (manual vs PPX-UV). Colony counts were described with means, medians and the interquartile range (q1-q3). Colony count reductions were calculated as the percent change from pre-cleaning to post-cleaning. Baseline counts were not equivalent per Wilcoxon Rank Sum test, therefore adjusting for the pre-cleaning counts was appropriate. Post-cleaning colony counts were modeled as a function of baseline count and cleaning protocol. Poisson regression is appropriate for modeling count data where the mean is equal to the variance, however, when the data are over-dispersed as these were with the variance greatly exceeding the mean, Poisson regression will under-estimate the standard errors whereas negative binomial regression produces more accurate estimates [16]. Therefore, we used negative binomial regression to estimate the association of cleaning protocol (manual vs PPX-UV) with final colony count, adjusting for baseline counts. The strength of association between predictor and outcome is reported as a regression coefficient for change in the log of counts when the factor is present, and can be exponentiated as an incident rate ratio with 95% confidence interval (IRR, CI95). The IRR is similar to the more familiar odds ratio where a significant effect is one whose CI95 excludes 1. The IRR is the factor by which the expected colony count is multiplied per 1-unit increase in the predictor. For the cleaning protocol, the predictor was either 0 (PPX-UV) or 1 (manual cleaning).

Results

Colonies in 20 rooms (10 per arm) prior to cleaning varied by cleaning protocol: for HPC, manual (mean = 255, median = 278, q1-q3 132–304) vs PPX-UV (mean = 449, median = 365, q1-q3 332–530), and for MRSA, manual (mean = 127; median = 28.5; q1-q3 8–143) vs PPX-UV (mean = 108; median = 123; q1-q3 14–183). These baseline plate counts were not equivalent and were not normally distributed. After cleaning, the counts averaged 60 colonies (76% reduction; manual) vs 8 colonies (98% reduction; PPX-UV) for HPC, and 11 colonies (91% reduction; manual) vs 1 colony (99% reduction) for MRSA. The HPC count was significantly greater for the manual cleaning arm relative to the PPX-UV arm, adjusting for baseline total HPC counts in the rooms (IRR = 12.9, CI95 3.5-47.8, p < .01), meaning the expected count was multiplied by a factor of 13 when the independent variable increased by one unit from 0 (machine) to 1 (manual). Similarly, the MRSA count was significantly higher in the manual cleaning arm relative to the PPX-UV arm (IRR = 7.2, CI95 1.3-41.4, p < .03). See Tables 1, 2, 3. The majority of the difference in post-cleaning colonies was due to high residual counts on the toilet seats in the manual arm. The number of MRSA-positive sites per room after manual cleaning was 0 (4 rooms), 1 (4 rooms), or 2 (2 rooms), and the number of MRSA-positive sites per room after PX-UV cleaning was 0 (7 rooms), 1 (2 rooms), or 2 (1 room). The average number of minutes spent cleaning a room was 49 minutes including device time (SD = 13) for PPX-UV and 63 minutes (SD = 29) for manual cleaning (t-statistic = 1.5; df = 12.1; p = .17, n.s.). The average size of a patient room (living & bathroom) in the manual arm was 23 m$^2$ and in the PPX-UV arm was 25 m$^2$. 

Table 1 Methicillin-resistant *Staphylococcus aureus* and bacterial heterotrophic plate counts before and after disinfection per room for five high-touch surfaces total

| Colony Count Measures of Central Tendency and Variability by Room Mean; Median (IQR) |
|---------------------------------|---------------------------------|-------|
|                                 | Before                          | After | Reduction |
| **HPC**                         |                                 |       |           |
| Manual arm                      | 255.0; 278.0 (132-304)          | 60.4; 31.0 (15-70) | 76.3% |
| PPX-UV arm                      | 449.0; 364.5 (332-530)          | 8.4; 4.0 (1-10) | 98.1% |
| **MRSA**                        |                                 |       |           |
| Manual arm                      | 127.3; 28.5 (8-143)             | 11.3; 1.0 (0-4) | 91.1% |
| PPX-UV arm                      | 108.2; 123.0 (14-183)           | 0.7; 0.0 (0-1) | 99.4% |

HPC: Bacterial heterotrophic plate counts.
MRSA: Methicillin-resistant *Staphylococcus aureus*.
PPX-UV: Portable pulsed xenon ultraviolet.
### Table 2 Estimated effect of cleaning protocol on colony counts: manual cleaning vs portable pulsed ultraviolet machine cleaning (N = 20 Rooms)

<table>
<thead>
<tr>
<th>Type of Colonies</th>
<th>Regression Coefficient (beta)</th>
<th>95% CI for beta</th>
<th>Incident Rate Ratio (exp(beta))</th>
<th>95% CI for IRR</th>
<th>Chi-square statistic</th>
<th>Pr</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>MRSA</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Baseline count</td>
<td>0.004</td>
<td>&lt;0.0-0.001</td>
<td>--</td>
<td>--</td>
<td>3.24</td>
<td>0.07</td>
</tr>
<tr>
<td>Manual cleaning</td>
<td>2.0</td>
<td>0.2-3.7</td>
<td>7.2</td>
<td>1.3-41.4</td>
<td>4.91</td>
<td>0.03</td>
</tr>
<tr>
<td><strong>HPC</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Baseline count</td>
<td>0.002</td>
<td>&lt;0.0-0.01</td>
<td>--</td>
<td>--</td>
<td>1.49</td>
<td>0.22</td>
</tr>
<tr>
<td>Manual cleaning</td>
<td>2.6</td>
<td>1.3-3.8</td>
<td>12.9</td>
<td>3.5-47.8</td>
<td>14.7</td>
<td>&lt;0.01</td>
</tr>
</tbody>
</table>

### Table 3 Total positive plates & colony counts per site by bacterial heterotrophic colony counts and Methicillin-resistant *Staphylococcus aureus* before and after manual and UV light disinfection for 5 high touch surfaces

<table>
<thead>
<tr>
<th>Site</th>
<th>HPC Positive plates (Colony Count)</th>
<th>MRSA Positive plates (Colony Count)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Bed rail</strong></td>
<td>10/10 (774) 10/10 (30) 10/10 (1079) 0/10 (0) 8/10 (308) 0/10 (0) 8/10 (188) 0/10 (0)</td>
<td></td>
</tr>
<tr>
<td><strong>Call button</strong></td>
<td>10/10 (494) 6/10 (64) 10/10 (1121) 3/10 (54) 9/10 (89) 1/9 (1) 8/10 (286) 1/10 (1)</td>
<td></td>
</tr>
<tr>
<td><strong>Tray table</strong></td>
<td>10/10 (311) 8/10 (21) 10/10 (293) 1/10 (4) 9/10 (48) 1/10 (1) 5/10 (10) 1/10 (1)</td>
<td></td>
</tr>
<tr>
<td><strong>Bathroom handrail</strong></td>
<td>10/10 (392) 10/10 (91) 10/10 (988) 5/10 (20) 8/10 (269) 3/10 (86) 9/10 (265) 2/10 (5)</td>
<td></td>
</tr>
<tr>
<td><strong>Toilet seat</strong></td>
<td>10/10 (579) 7/10 (398) 10/10 (1009) 2/10 (6) 9/10 (559) 3/10 (25) 8/10 (333) 0/10 (0)</td>
<td></td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>50/50 (2550) 41/50 (604) 50/50 (4490) 11/50 (84) 43/50 (1273) 8/49 (113) 38/50 (1082) 4/50 (7)</td>
<td></td>
</tr>
</tbody>
</table>

HPC: Bacterial heterotrophic plate counts.
MRSA: Methicillin-resistant *Staphylococcus aureus*.
PPX-UV: Portable pulsed xenon Ultraviolet.
Discussion

Our study showed that a “no-touch” semi-automated system, the PPX-UV, was effective in substantially reducing the heterotrophic bacterial and MRSA burden on high-touch surfaces in rooms vacated by MRSA-positive patients. PPX-UV disinfection may add to the armamentarium against HAI’s without risking the adaptive genetic resistance incurred by pharmaceutical weapons. Implementation including training EMS personnel to operate the device was minimal, and time spent cleaning was not increased. Because there were separate cycles for bathroom and living room, the surface reduction in aerobic colony counts may be better than with other UV systems; a head-to-head comparison of UV area disinfection devices may be warranted [12,13].

Consistency in patient room-cleaning is needed. High residual colony counts were observed on the toilet seats post-cleaning in the manual arm. This may be due to human inconsistency or memory failure regarding which parts of the room have been cleaned, a common problem with repetitive tasks. A highly structured approach that involves educational, procedural, and administrative interventions with repeated performance feedback to EMS by monitoring the thoroughness of cleaning with either adenosine 5’-triphosphate (ATP) assays or fluorescent dyes has been shown to be successful in reduction of microbial contaminants in patient rooms [17,18]. Other intervention programs such as monitoring room cleanliness using checklists may also result in significant improvement in cleaning practices [19]. Although such interventions improve cleaning, in the post-intervention period the increase is no more than 85% [20], and the effects may decrease post-intervention unless ongoing feedback to environmental services staff is sustained [9]. Thus empowering EMS with a “no touch” semi-automated system such as PPX-UV to substantially reduce the microbial burden on high-touch surfaces, combined with education and feedback, may help us achieve the desired effect of thorough disinfection for every vacated patient room. Training on the device was simple; EMS personnel commented they could easily incorporate this system into their routine cleaning practices. The usual run time of PPX-UV was 15 minutes and required 2–3 minutes of additional setup time. Hence the authors believe PPX-UV disinfection could be integrated into routine hospital cleaning operations without disruption of patient flow or undue burden on EMS staff.

Our study adds to the existing debate in literature about one long cycle vs several shorter cycles for UV disinfection and about a UV device’s effect on aerobic surface colony count reduction. Since separate cycles are needed for bathroom and two positions for living room, the surface reduction in aerobic colony counts was similar to studies of other UV systems that had separate bathroom cycles and perhaps better surface reduction as compared to studies with no separate bathroom cycles [11-13]. In the PPX-UV arm, the focus was to get the rooms aesthetically clean by manually wiping all grossly soiled surfaces. We believed that our efforts to focus on the aesthetic cleaning, thus allowing for a truncated pre-cleaning routine is consistent with new published literature. Anderson et al. showed that despite lack of pre-cleaning there was statistically significant reduction in organisms such as VRE and C.diff spores [21]. Zhang et al. also showed that the organic material from the hospital rooms only modestly affected UV killing of spores [22]. The above research findings could explain why PPX-UV arm had lower counts inspite of a truncated pre-cleaning routine. The manufacturer recommended the same cycle times for patient rooms with c.diff spores based on preliminary lab data, and studies are underway at another site to examine the efficacy on c.diff spores in a hospital setting, however, future independent research should directly assess sporidical capacity of the PPX-UV. Federally funded multi-site comparative study with
multiple microbial targets is currently underway. Future research should also assess patient outcomes and cost-effectiveness for major and emergent infectious agents in healthcare systems with and without systematic PPX-UV cleaning.

Our study has several limitations: it was not designed to assess impact on the actual transmission of healthcare-acquired infections. The number of surfaces and rooms sampled was small but similar in size to previously published studies [11,12]. The protocol did not evaluate the incremental impact of UVC treatment following routine cleaning, a process to be evaluated in our next study. The delay to culture introduced by the overnight transport process may have influenced culture viability, however, both manual and PPX-UV samples experienced the same transport periods thus reducing likelihood of bias from this source of variability. EMS personnel were not blinded to the study nor to the protocol to be used in each room. Supervisors commented that they were taking longer than usual to clean the rooms, suggesting increased vigilance; this would potentially bias our results toward the null. Better differential effects might be achieved in a real-world implementation where lapses in EMS attentiveness may occur unpredictably. The rather high post-cleaning MRSA counts in the manual cleaning arm may point to another area of research, comparing the quality of manual cleaning protocols across hospital systems. It is possible that higher bacterial counts in the manual arm may be due to lack of actual manual cleaning process rather than the lack of efficacy of the manual cleaning process. While it is possible that ours is the only facility in the VA system whose cleaning crew has inconsistency in cleaning thoroughness, we suspect it is more a part of the human condition. Two multisite trials that we know of are currently in progress and should provide larger scale results on PPX-UV effectiveness.

Conclusions

In conclusion, PPX-UV technology appears to be superior to manual cleaning alone for MRSA and HPC. We believe incorporating 15 minutes of PPX-UV exposure time to current hospital room cleaning practice can improve the overall cleanliness of patient rooms with respect to selected micro-organisms by a factor of 7–12 in a sustainable manner. Outcome studies are being conducted to assess the economic and clinical impact of this technology.

Competing interests

This study's laboratory activity including use of the PPX-UV machine was supported by a grant from Xenex Healthcare Services, LLC. No author has identified a competing interest regarding the study beyond working for the institution studied (Department of Veterans Affairs, Veterans Health Administration).

Authors’ contributions

All authors made a significant contribution to the project. CJ and RQ developed the methodology, protocol, performed data collection and manuscript preparation. TH and JW carried out the microbiology and contributed to the manuscript. JZ and LC participated in statistical analysis and contributed to the manuscript. All authors read and approved the final manuscript.
Acknowledgements

The authors would like to thank Elicia Greene and Christine Southard from Infection Prevention and Control, Maggie McCarthy, Ruth Merton and Paul Hicks from Research Foundation at Central Texas Veterans Health Care System. The authors received grant support from the Veterans Health Administration for unrelated studies. This work was supported by the Central Texas Veterans Health Care System (Temple, Texas), with additional support from Scott & White Healthcare (Temple, Texas) and the jointly sponsored Center for Applied Health Research (Temple, Texas). The views expressed in this article are those of the author(s) and do not necessarily represent the views of the Department of Veterans Affairs.

Funding

This study’s laboratory activity including use of the PPX-UV machine was supported by a grant from Xenex Healthcare Services, LLC.

References


<table>
<thead>
<tr>
<th>Patient Outcome Studies</th>
<th>Infection</th>
<th>Infection Rate Reduction (%)</th>
<th>p-value</th>
<th>Statistical Significance*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Levin (2013)</td>
<td>Clostridium difficile (C. difficile)</td>
<td>53%</td>
<td>0.01</td>
<td>Yes</td>
</tr>
<tr>
<td>Simmons (2013)</td>
<td>Methicillin-resistant Staphylococcus aureus (MRSA)</td>
<td>57%</td>
<td>0.001</td>
<td>Yes</td>
</tr>
<tr>
<td>Haas (2014)</td>
<td>C. difficile</td>
<td>17%</td>
<td>0.02</td>
<td>Yes</td>
</tr>
<tr>
<td></td>
<td>MRSA</td>
<td>27%</td>
<td>0.007</td>
<td>Yes</td>
</tr>
<tr>
<td></td>
<td>Vancomycin-Resistant Enterococci (VRE)</td>
<td>18%</td>
<td>0.002</td>
<td>Yes</td>
</tr>
<tr>
<td></td>
<td>Multidrug-resistant organisms (MDROs)</td>
<td>20%</td>
<td>0.04</td>
<td>Yes</td>
</tr>
<tr>
<td>Miller (2015)</td>
<td>C. difficile</td>
<td>57%</td>
<td>0.02</td>
<td>Yes</td>
</tr>
<tr>
<td>Nagaraja (2015)</td>
<td>C. difficile</td>
<td>70%</td>
<td>&lt;0.001</td>
<td>Yes</td>
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<tr>
<td>Fornwalt (2015)</td>
<td>Surgical Site Infections (SSIs)</td>
<td>100%</td>
<td>0.01</td>
<td>Yes</td>
</tr>
<tr>
<td>Vianna (2015)</td>
<td>MDROs</td>
<td>61%</td>
<td>0.01</td>
<td>Yes</td>
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<tr>
<td>Catalanotti (2016)</td>
<td>SSIs</td>
<td>45%</td>
<td>0.04</td>
<td>Yes</td>
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<tr>
<td>Kovach (2017)</td>
<td>Nursing home-acquired infections (urinary tract, respiratory, skin, enteric)</td>
<td>40%</td>
<td>0.004</td>
<td>Yes</td>
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</tbody>
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<table>
<thead>
<tr>
<th>Hospital Environment Studies</th>
<th>Organism(s)</th>
<th>Contamination Reduction (%)</th>
<th>Setting</th>
<th>Notable Findings</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stibich (2011)</td>
<td>VRE</td>
<td>100%</td>
<td>MD Anderson</td>
<td>21 surfaces from 12 rooms</td>
</tr>
<tr>
<td>Laboratory Studies</td>
<td>Organism(s)</td>
<td>Log reduction</td>
<td>Setting</td>
<td>Notes</td>
</tr>
<tr>
<td>---------------------</td>
<td>-----------------------------</td>
<td>---------------</td>
<td>--------------------------------</td>
<td>------------------------------------------------------------</td>
</tr>
<tr>
<td>Nerandzic (2015)</td>
<td>C. difficile, MRSA, VRE</td>
<td>0.55, 1.85, 0.6</td>
<td>Cleveland Veterans Affairs</td>
<td>Used dubious laboratory methods</td>
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<tr>
<td>Stibich (2016)</td>
<td>Multiple organisms</td>
<td>1.54 to &gt;9</td>
<td>BSL-4 Laboratory</td>
<td>Third-party testing using rigorous methods</td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>Patient Satisfaction Study</th>
<th>Intervention</th>
<th>HCAHPS Score</th>
<th>Setting</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fornwalt (2014)</td>
<td>Patient-awareness campaign</td>
<td>Rose from 76% to 87.6%</td>
<td>Acute care hospital</td>
<td>Hospital received 1% of at-risk reimbursement</td>
</tr>
</tbody>
</table>
To determine whether a result is statistically significant, a researcher calculates a $p$-value, which is the probability of observing an effect given that the null hypothesis is true. A $p$-value $>0.05$ indicates that random chance cannot be ruled out. See Devore, Jay L. (2011). *Probability and Statistics for Engineering and the Sciences* (8th ed.), pp. 300–344.

References

*Patient Outcome Studies – Pulsed-Xenon UV*

Major Article

Effect of pulsed xenon ultraviolet room disinfection devices on microbial counts for methicillin-resistant Staphylococcus aureus and aerobic bacterial colonies

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Key Words: Hospital-associated infections, no-touch disinfection, methicillin-resistant Staphylococcus aureus, aerobic colonies, implementation

Background: Inadequate environmental disinfection represents a serious risk for health care–associated infections. Technologic advancements in disinfection practices, including no-touch devices, offer significant promise to improve infection control. We evaluated one such device, portable pulsed xenon ultraviolet (PX-UV) units, on microbial burden during an implementation trial across 4 Veterans Affairs hospitals.

Methods: Environmental samples were collected before and after terminal room cleaning: 2 facilities incorporated PX-UV disinfection into their cleaning protocols and 2 practiced manual disinfection only. Specimens from 5 high-touch surfaces were collected from rooms harboring methicillin-resistant Staphylococcus aureus (MRSA) or aerobic bacteria colonies (ABC). Unadjusted pre-post count reductions and negative binomial regression modeled PX-UV versus manual cleaning alone.

Results: Seventy samples were collected. Overall, PX-UV reduced MRSA and ABC counts by 75.3% and 84.1%, respectively, versus only 25%-30% at control sites. Adjusting for baseline counts, manually cleaned rooms had significantly higher residual levels than PX-UV sites. Combined analyses revealed an incident rate ratio of 5.32 (P = .0024), with bedrails, tray tables, and toilet handrails also showing statistically superior PX-UV disinfection.

Conclusions: This multicenter study demonstrates significantly reduced disinfection across several common pathogens in facilities using PX-UV devices. Clinical impact of laboratory reductions on infection rates was not assessed, representing a critical future research question. However, such approaches to routine cleaning suggest a practical strategy when integrated into daily hospital operations.

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care costs annually in the United States.

An estimated 20%-40% of all HAIs result from cross-contamination via health care personnel either by direct patient contact or by touching contaminated environmental surfaces. Patients admitted to a room previously occupied by a MRSA-positive patient also have significantly higher risk of acquiring that infection. Additionally, new carriers have a higher risk of developing MRSA infections in the year after acquisition. High-touch surfaces, such as patient bed rails or tray tables, present the biggest risk of HAI acquisition for patients; however, appropriately decontaminating these surfaces could possibly prevent future infections. Manual cleaning with Environmental Protection Agency–approved disinfectants is the current standard of disinfection procedure; however, such disinfection effort requires supervision, frequent reinforcement, education, and performance feedback using a variety of techniques to ensure environmental management service (EMS) staff maintain effective cleaning results.

No-touch surface decontamination technologies that use ultraviolet light may be effective at reducing microbial burden in the laboratory and controlled environments, with increasing inpatient efforts now being on such infection control strategies to decrease bioburden levels and potentially achieve lower HAI rates. Although effective to varying degrees, many of the devices require additional time to complete disinfection, with estimates ranging from 15 minutes–1 hour per room, potentially restricting widespread routine hospital usage. Furthermore, there are numerous makers of no-touch devices with limited scientific evidence that may confuse users and impact adaptation within hospitals. Additionally, generalizability has been reduced by data limited to single hospital settings or in comparison with standard disinfection processes across many facilities. As such, previously published data on pulsed xenon ultraviolet (PX-UV) technology have lacked multicenter comparison and real-world effectiveness. Here we present our study that compares the adoption of PX-UV technology into standard terminal room cleaning protocols in 2 facilities with manual cleaning for reduction of bacteria frequently associated with HAI.

**METHODS**

**PX-UV devices**

The portable pulsed xenon ultraviolet light device is this study (Xenex Healthcare Disinfection Services, San Antonio, TX) measures approximately 76.2 × 50.8 × 96.6 cm, features a user-friendly touch screen interface, features an integrated cooling system, and features a reflector system to focus ultraviolet light on high-touch surfaces. There are numerous safety features, including special glass to reduce visual light intensity and ultrasonic sensors to terminate pulsing, if movement is detected in the room. Briefly, PX-UV light is absorbed by and fuses with the microorganism DNA, resulting in its deactivation.

The devices are operated by EMS staff, who receive comprehensive training and monitoring, and are used in empty patient rooms during terminal discharge cleaning before the next patient is admitted; in shared rooms, the other patient is briefly relocated to avoid accidental ultraviolet exposure. First, EMS manually cleaned the bathroom using Environmental Protection Agency–approved disinfectant (eg, bleach, quaternary ammonium compounds) per local hospital protocol, and then placed the device in the bathroom to complete a 5-minute PX-UV cycle at roughly 450 flashes a cycle. Meanwhile, EMS staff manually cleaned the hospital main room with particular attention to visibly soiled areas. The device was then moved to the central room area for a second 5-minute cycle, after which the EMS staff member reentered the room to flip available surfaces, such as the phone and remote control, and the device was repositioned for a final 5-minute cycle. Device positioning within the room was based on suggested protocols by the manufacturer and the specific room design but generally involved device placement on either side of the bed (see Fig 1, with three cleaning cycle positions noted). We used this approach during our smaller single-site pilot study. Therefore, total disinfection time is roughly 15 minutes per room.

This implementation study was conducted from February 2013-March 2015 at 4 Veterans Affairs facilities as one primary objective in a comprehensive study examining the overall effectiveness of PX-UV devices for reducing colony counts of important microbial pathogens. Two hospitals (Temple, TX Veterans Health Care System [CTX] and San Antonio, TX Veterans Health Care System [STX]) added the PX-UV devices to standard manual room cleaning on terminal cleaning and represented the intervention sites, whereas 2 other facilities served as control sites with standard manual cleaning only (Portland, OR and Birmingham, AL). All 4 facilities collected microbial samples from several high-touch surfaces of patient rooms as subsequently described, with the samples sent to an independent Veterans Affairs laboratory (Cleveland, OH). Per standard hospital protocols, all rooms were terminally disinfected after every patient discharge or transfer, with site researchers collecting microbial swabs of infectious agents before and after cleaning during the 2-year study.
period. Manual cleaning for each site was conducted according to local protocol and inspected by research staff using a standardized (Centers for Disease Control and Prevention) checklist to monitor manual cleaning efforts. This study was approved by the Veterans Affairs Central Institutional Review Board and by the research and development service at all 4 sites.

Environmental sampling and testing procedure

For each room, we collected samples of microbiologic classes subsequently described from 5 separate high-touch surfaces (ie, bedrail, toilet seat, bathroom handrail, call button, tray table) before and after either standard cleaning or PX-UV disinfection. For a room to be included, we required occupancy for at least 48 hours prior to discharge, it contain a single bed with an unshared bathroom, and availability of research staff to collect samples. As the most common pathogen in our facilities, a room was included if the occupant patient was infected or colonized by MRSA; additionally, rooms of occupant patients with or without other known multidrug-resistant pathogens were used to sample for aerobic bacteria colonies (ABC). MRSA and ABC samples were obtained using nonelective RODAC contact plates (Hardy Diagnostics, Santa Monica, CA). For flat surfaces, the contact plate was firmly pressed for 5 seconds; for nonflat surfaces, a roll-plate technique was used. A regular flocked swab premoistened with approximately 0.1 mL of the liquid Amies transport media was used. Approximately half the surface size (eg, half of a tray table, half of the bathroom grab bar) was sampled using the premoistened swab by applying firm pressure in a zigzag motion; then the swab was placed in the sterile polypropylene screw cap tube with a conical-shaped bottom filled with 1 mL of liquid Amies transport medium. All samples were accessioned with unique identification numbers prior to incubation, which were then transported on ice overnight to an independent blinded laboratory. The microbiologist there was blinded to sample site and device status.

Confirmation of microbes

On arrival in the central laboratory, samples taken by RODAC plates were incubated for 48-72 hours at 37°C. The aerobic colony counts were estimated by counting the actual number of colonies per quadrant on the RODAC plates. Similarly, the number of MRSA colonies were estimated based on the presence of mauve-colored colonies, which were later confirmed to be MRSA using a latex agglutination test (Staphaurex kit; Remel, Lenexa, KS).

Statistical analyses

Unadjusted mean pre- and postdisinfection colony counts for both MRSA and ABC were calculated along with reduction percentages, per room surface and overall total. Multivariable models were run to adjust for any before cleaning differences because plate counts were not equivalent at baseline and not normally distributed. A negative binomial (Poisson) regression was used to determine the association of PX-UV disinfection versus manual cleaning to microbial counts. Contact plates resulting in confluent growth were designated as too numerous to count for reporting purposes. Too numerous to count plates and any plates with a colony count ≥ 250 for MRSA were assigned a value of 250 colonies for statistical analysis. This was done to limit the effect of a few outliers skewing the data and hence overestimating the potential effect of PX-UV light on MRSA. The strength of the association between reductions in colony counts and the PX-UV device is reported as an adjusted incident rate ratio (IRR), similar to an odds ratio in a standard logistic regression model.

RESULTS

A total of 70 different microbial samples were analyzed (ABC: n = 31; MRSA: n = 39), with 42 of the samples collected at the PX-UV intervention facilities.

Microbial reduction

ABC reduction

 Colony counts in 31 rooms (19 PX-UV rooms and 12 manual rooms) experienced an overall ABC decrease, an average drop from 397 to 98 for PX-UV device arms (75.3%) versus 151 to 111 (26.5%) for manual arms (Tables 1 and 2). Of the 19 PX-UV rooms, 15 were from the Central Texas facility which experienced a mean 78.0% reduction and 4 were from the South Texas hospital with an average 52.0% reduction. Manual cleaning rooms were all collected at the Portland site. Turning to the multivariable models using negative binomial regression, the overall residual ABC count remaining in a room was significantly greater for the manual cleaning arms relative to the PX-UV arms, adjusting for baseline colony counts in the rooms (IRR = 3.2; 95% confidence interval [CI], 1.4-7.3; P = .007). Concerning specific high-touch room surfaces, a similar relationship was observed for tray table surfaces (IRR = 3.1; 95% CI, 1.8-4.2; P < .0001) and bedrails (IRR = 2.4; 95% CI, 1.4-3.9; P = .001), with smaller effects for other surfaces.

MRSA reduction

Among the 39 rooms sampled (23 PX-UV rooms and 16 manual rooms), an overall MRSA pre-post cleaning reduction was observed, with 84.1% (16.9 to 2.7) for PX-UV rooms and 45.1% (31.8 to 17.4) among manually cleaned rooms. By facility, of the 23 PX-UV rooms, 15 of the PX-UV rooms were from CTX (an 89.3% reduction) and 8 from STX (50% reduction). Manual cleaning rooms comprised 14 rooms from Portland (82.8% reduction), whereas the 2 from Birmingham witnessed a mean 27.2% reduction. In zero-inflated Poisson regression models for MRSA alone, the adjusted model demonstrated a significant PX-UV overall reduction (IRR = 2.8; 95% CI, 2.7-3.0; P < .0001). In addition, the residual colony count for MRSA was substantially greater for the manual cleaning arm relative to the PX-UV arm for several locations, most notably the call button (IRR = 9.4; 95% CI, 3.6-24.3; P < .0001) and toilet handrail (IRR = 7.6; 95% CI, 7.4-7.9; P < .0001). A slightly though marginally insignificant negative association was observed for the bedrail surfaces (ie, manual cleaning was more effective than PX-UV cleaning).

Combination of MRSA and ABC

When combining the 2 highly prevalent laboratory samples, colony counts in those 70 rooms (42 PX-UV rooms and 28 manual rooms) experienced an overall raw MRSA + ABC decrease, averaging 143 ± 216 (median, 36) for PX-UV cleaning and only 25 ± 93 (median, 2) for manual cleaning. Overall count reduction was 75.7% for PX-UV cleaning and 30.6% for manual cleaning. Of the 42 PX-UV rooms, 30 were from CTX (78.5% reduction) and 12 were from STX (51.9% reduction). Manual cleaning rooms comprised 26 rooms at Portland (31.2% reduction) and 2 rooms from Birmingham (27.2% reduction). In adjusted models, the overall residual colony count was significantly greater for the manual cleaning arm relative to the PX-UV arm (IRR = 2.5; 95% CI, 2.4-2.6; P < .0001). A similar relationship was observed for the toilet handrail (IRR = 3.6; 95% CI, 1.3-4.4), bedrail (IRR = 4.6; 95% CI, 3.9-5.6), tray table (IRR = 2.6; 95% CI, 2.3-3.0), and call button and telephone (IRR = 2.3; 95% CI, 1.5-3.6) surfaces, all significant at P < .0001.
DISCUSSION

Our results show that PX-UV disinfection reduced the overall bacterial bioburden in patient rooms when incorporated into terminal room disinfection more effectively compared with standard manual disinfection. The reduction in aerobic colonies was statistically significant when adjusting for the baseline colony counts. The overall MRSA colony count was lower in the enhanced disinfection in the intervention sites but not statistically significantly different than manual clean sites.

Previously published literature, primarily for smaller single-site studies, has shown MRSA and *C. difficile* colony count reduction when enhanced disinfection was used both for PX-UV and other mercury-based ultraviolet sources. Prior work has also demonstrated that PX-UV is effective on vancomycin-resistant enterococci as well; however, we did not specifically test for that bacteria type in the current study. Our results are similar to earlier studies regarding ABC reduction and PX-UV devices. The PX-UV sites showed larger reductions in MRSA colony counts from pre- to postclean compared with the manual clean sites (84.1% vs 45.1%, respectively); however, not all differences in specific high-touch surfaces were statistically significant when adjusting for baseline colony counts. Our results may differ from previous studies regarding MRSA because we compared different sites with facility-level differences in cleaning practices and contamination levels.

Interestingly, device effectiveness at CTX was slightly better than STX; however, both sites demonstrated statistically significant improvements versus the control hospitals. Possible explanations for this finding might at least be partially attributable to earlier first implementation of PX-UV disinfection, where our pilot study was conducted, and hence more device experience and operational support; minor differences in patient acuity (although our administrative data analysis showed no differences in demographics, comorbidities, or other relevant characteristics); or unobserved variation in EMS training, manual cleaning techniques, or device procedures. Other possibilities include the fact that ultraviolet light works better when device placement offers a more direct line of sight compared with indirect angles, or if manual precleaning is not adequate (eg, a ketchup mark left on a tray surface), the ultraviolet light may not fully penetrate that area. However, we maintained strict standards of staff training across sites, use of PX-UV devices, and documentation of terminal room cleaning efforts (via the Centers for Disease Control and Prevention checklist) revealed no site differences.

A primary strength of this study is that it was conducted in multiple facilities through a real-world implementation trial over a 2-year period. As such, this was the first such PX-UV trial across several hospitals; however, subsequent studies are now exploring these devices in larger multisite projects, and in smaller focused projects in a variety of different treatment settings (operating rooms, patient rooms, and patient rooms).

<table>
<thead>
<tr>
<th>Location</th>
<th>Arm</th>
<th>Precleaning</th>
<th>Postcleaning</th>
<th>Reduction, %</th>
</tr>
</thead>
<tbody>
<tr>
<td>ABC</td>
<td></td>
<td>n: Mean ± SD</td>
<td>Median (Min-Max)</td>
<td>n: Mean ± SD</td>
</tr>
<tr>
<td>Toilet seat</td>
<td>Control</td>
<td>12</td>
<td>29.2 ± 28.6</td>
<td>16 (2-100)</td>
</tr>
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<td>52.5 ± 68</td>
<td>36 (0-250)</td>
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<tr>
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<td>82 (2-250)</td>
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<tr>
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<td>19</td>
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<td>27 (3-250)</td>
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<tr>
<td>Call button or telephone</td>
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<tr>
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<td>Intervention</td>
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<td>95.2 ± 94.3</td>
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<td>Overall</td>
<td>Control</td>
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<td>113 (18-784)</td>
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<td>396.8 ± 313.9</td>
<td>376 (40-1220)</td>
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<tr>
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<th>Arm</th>
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<th>Postcleaning</th>
<th>Reduction, %</th>
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<td>ABC</td>
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<td>16</td>
<td>8.3 ± 27.3</td>
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<td>0 (0-40)</td>
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<tr>
<td>Bedrail</td>
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<td>16</td>
<td>16.7 ± 51.5</td>
<td>0 (0-200)</td>
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<tr>
<td></td>
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<td>0.6 ± 1.4</td>
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<td>2.5 ± 10</td>
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<td>16.7 ± 51.2</td>
<td>0 (0-40)</td>
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<td>Control</td>
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<tr>
<th>MRSA + ABC</th>
<th>Location</th>
<th>Arm</th>
<th>Precleaning</th>
<th>Postcleaning</th>
<th>Reduction, %</th>
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<tbody>
<tr>
<td>ABC</td>
<td>Toilet seat</td>
<td>Control</td>
<td>28</td>
<td>17.3 ± 29.3</td>
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<td>Intervention</td>
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<td>32.8 ± 66.4</td>
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<tr>
<td>Tray table</td>
<td>Control</td>
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<td>18.8 ± 49.1</td>
<td>3 (0-250)</td>
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<td>48.9 ± 78.5</td>
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<td>34.8 ± 68.5</td>
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<td>19 ± 51.1</td>
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<td>42</td>
<td>48 ± 77.1</td>
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</table>

*ABC, aerobic bacteria colonies; Max, maximum; Min, minimum; MRSA, methicillin-resistant *Staphylococcus aureus.*
which helps validate practical implications and generalizability compared with single-center smaller studies. Another strength was that we collected multiple isolates from several high-touch surface samples, affording us greater ability to examine >1 organism. This true implementation project had strong support from infectious disease providers and clinical leadership at all our hospitals, collectively interested in the study findings to help evaluate local infection control options.

Our study had several limitations given the nature of a real-world implementation trial: in addition to finite overall samples, one site (Birmingham, AL), also had minimal contribution to ABC or MRSA sampling, which limited conclusions. The availability of terminal rooms for specimen collection and PX-UV disinfection was not predictable and often subject to discharge timing (weekends and evenings) or nursing priorities to admit the next patient, affecting the sampling frame and size. This fact has significant implications for widespread use of PX-UV devices or other promising innovative technology: the potential impact of daily clinical priorities. Further, there may have been unmeasured facility differences (eg, cleaning practices regarding disinfectant usage, other infection control policies, frequency or fidelity to PX-UV use at the 2 implementation sites) that may have influenced our findings. Finally, we also note that ABC count represents general contamination rather than specific multidrug-resistant organisms known to cause an infection.

In conclusion, PX-UV technology was effective at reducing overall bacterial counts and significantly more successful than manual disinfection alone in reducing the ABC counts on hospital surfaces. Further evaluation focusing on clinically meaningful reduction in HAIs is of paramount importance in justifying the cost and effort in implementing this promising technology in battle against pernicious hospital infections.

Acknowledgments

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References