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BRIEF REPORT

# Perioperative Bacterial Contamination From Patients on Contact Precaution in Operating Room Environment

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We investigated the microbial burden on the operating room environment when patients on contact precautions for a multidrug-resistant pathogen received surgery. Our study demonstrated that the perioperative environment was contaminated with aerobic bacteria and methicillin-resistant *Staphylococcus aureus* (MRSA) after surgery, and that MRSA persisted environmentally even after cleaning and disinfection, highlighting the need for meticulous cleaning and disinfection in the perioperative environment.

**Keywords.** environment; microbial contamination; operating room.

Environmental surfaces in hospital rooms of colonized and/or infected patients are frequently contaminated with healthcare-associated pathogens. These pathogens can survive on environment surfaces for a prolonged period (eg, 7 days to 7 months for *Staphylococcus aureus*, 5 days to 4 months for *Enterococcus* spp, and up to 5 months for *Clostridioides difficile* [spores]) [1]. The contaminated healthcare environment, including perioperative areas, serves an important role in transmission of pathogens [2, 3]. Patients admitted to a room previously occupied by a patient colonized and/or infected with a healthcare-associated pathogen have an increased likelihood of acquiring multidrug-resistant (MDR) pathogens [2]. Studies have described that cleaning practices in operating rooms (ORs) and anesthesia work areas are imperfect [3, 4]; therefore, environmental surfaces remain contaminated with pathogens [3, 5]. Removal of MDR pathogens from environment surfaces in ORs is essential to minimize the risk of surgical site infections, especially of implanted orthopedic prostheses [6].

There are limited studies on the level of contamination of ORs during the surgery of a patient on contact precautions and the risk to the next surgery patient after room cleaning and/or disinfection. Therefore, we investigated the microbial burden on OR environment where patients on contact precautions received surgery, and we assessed the impact of cleaning and/or disinfection on contamination of environmental sites.

## METHODS

This investigation was conducted in ORs at the University of North Carolina Hospitals (Chapel Hill, NC), an ~960-bed tertiary care academic facility, between May and December 2015. This study involved 10 patients on contact precaution for a clinical isolate (ie, body fluid/tissue processed by the Microbiology Laboratory) of an MDR pathogen (methicillin-resistant *S aureus* [MRSA], 7; carbapenem-resistant *Enterobacteriaceae* [CRE] plus MRSA, 2; and vancomycin-resistant *Enterococcus* [VRE] plus MRSA, 1) who received surgery. Surfaces and floors were disinfected with an Environmental Protection Agency-registered disinfectant (quaternary ammonium compound) at the recommended concentration using a clean, wetted cloth for surfaces or clean, microfiber mop head for floors. Both the clean cloth and clean microfiber mop head were immersed into the disinfectant. A clean environment was re-established after each patient use by disinfecting items used during patient care (eg, OR table, intravenous poles) or contaminated environmental surfaces. In case of blood and/or body fluid spill clean-ups, the bulk material was removed with a 1:10 dilution of 5% sodium hypochlorite, then disinfected again. A perimeter of at least 6-feet around the OR patient table was mopped between cases.

Environmental sampling was performed by a medical technologist at the following time points: (1) immediately before the surgical patient's arrival in the OR, (2) after surgery but before the OR cleaning/disinfection, and (3) after the OR cleaning/disinfection. The cleaning status was visually assessed (eg, dirt/dust) after the OR cleaning/disinfection at the time of environmental sampling. Fifteen environmental sites per OR were sampled (ie, bed, arm rest, pyxis touchscreen, pyxis counter, computer hand rest, stool/chair/seat, floor [near, by OR bed], floor [far, by door], steel counter [small, near bed], steel counter [large, away from bed], anesthesia machine large screen, vent monitor, anesthesia machine drawer, small computer desk, and anesthesia steel counter), for both aerobic and anaerobic bacteria using Rodac plates (25 $cm^2$/plate). For each location (eg, bed) and sampling (eg, before patient), a specific location of the

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site sampled was recorded to avoid the exact location from being sampled more than once (eg, bed by head pillow, bed by arm rest, middle of bed). Visible contamination at the sampling site did not influence Rodac sampling. A total of 1520 environmental samples were collected from 15 OR sites for 10 surgical patients at 3 time points. The number of colony-forming units (CFUs) of aerobes and MDR pathogens (MRSA, CRE, VRE, and *C difficile*) were ascertained. The environmental surfaces were considered contaminated if at least 1 CFU/Rodac was detected. The number of 2 Rodac plates with >300 CFUs was calculated as 300 CFUs.

Pulsed-field gel electrophoresis (PFGE) was performed on 1% PFGE agarose gel with a CHEF-DR III system (Bio-Rad Laboratories, Richmond, CA) using the SmaI restriction enzyme (New England Biolabs, Inc., Ipswich, MA). Relatedness among MRSA strains was determined as described previously [7]. A total of 53 clinical (N = 9) and environmental (N = 44) MRSA isolates, including 9 isolates before patient arrival, 28 isolates after surgery but before cleaning/disinfection, and 7 isolates after cleaning/disinfection, were analyzed by PFGE.

Statistical analyses were performed using JMP 13 (Statistical Analysis System, Cary, NC) by the Wilcoxon test for continuous variables. A $P \leq .05$ was considered statistically significant.

### Patient Consent Statement

This research was approved by the Institutional Review Board of the University of North Carolina at Chapel Hill, and the requirement for written informed consent was waived.

## RESULTS

Microbial burden by an environmental site in ORs before patient arrival, before cleaning/disinfection, and after cleaning/disinfection was ascertained (Table 1). Overall, mean CFUs of aerobes per Rodac plate was 10.1 before patient arrival, 14.7 after surgery but before cleaning/disinfection, and 6.3 after cleaning/disinfection (Table 1). The mean CFU in ORs was significantly reduced after cleaning/disinfection, compared with that before patient arrival or after surgery but before cleaning/disinfection ($P < .0001$, respectively). The total CFU of aerobes before cleaning/disinfection (N = 7458) was reduced by 57% after cleaning/disinfection (N = 3192). Stool/chair/seat and floors were heavily contaminated with aerobes before patient arrival and after surgery but before cleaning and disinfection, and stool/chair/seat were still contaminated even after cleaning and disinfection. Seven environmental sites (47%) after cleaning/disinfection, including bed, arm rest, Pyxis counter, floor (OR bed), floor (by door), steel counter (small, near bed), and small computer desk, had significantly lower mean counts of aerobes than each of the sites before patient arrival or after surgery but

**Table 1. Microbial Burden by Environmental Site in Operating Rooms Before Patient Arrival, Before Cleaning, and After Cleaning**

| | Before Patient | | | Before Cleaning | | | After Cleaning | | | *P* Value | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| OR Site | No. of Rodac | Mean CFU/ Rodac | SD CFU/ Rodac | No. of Rodac | Mean CFU/ Rodac | SD CFU/ Rodac | No. of Rodac | Mean CFU/ Rodac | SD CFU/ Rodac | Before Patient vs Before Cleaning | Before Cleaning vs After Cleaning | Before Patient vs After Cleaning |
| Bed | 32 | 1.56 | 2.51 | 29 | 1.24 | 1.86 | 29 | 0.28 | 0.59 | NS | .0061 | .0015 |
| Arm rest | 30 | 1.2 | 1.19 | 27 | 1.33 | 1.49 | 27 | 0.33 | 0.78 | NS | .0014 | .0007 |
| Pyxis touchscreen | 31 | 3.23 | 3.87 | 31 | 2.42 | 2.92 | 31 | 3 | 3.28 | NS | NS | NS |
| Pyxis counter | 41 | 15.9 | 19.5 | 41 | 4.63 | 6.56 | 41 | 1.41 | 2.59 | .0023 | .0002 | <.0001 |
| Computer hand rest | 18 | 4.94 | 4.98 | 18 | 8.83 | 13.3 | 18 | 5.56 | 7.83 | NS | NS | NS |
| Stool/chair/seat | 41 | 46.4 | 56.8 | 41 | 55.8 | 77.5 | 41 | 32.3 | 40.9 | NS | NS | NS |
| Floor (near—door side) | 50 | 7.3 | 11.5 | 50 | 38.5 | 42.6 | 50 | 9.26 | 14.2 | <.0001 | <.0001 | NS |
| Floor (far—by door) | 50 | 24.1 | 24.7 | 50 | 41.4 | 35.7 | 50 | 7.62 | 10.3 | 0 | <.0001 | <.0001 |
| Steel counter (small—near bed) | 41 | 1.85 | 2.86 | 42 | 0.76 | 1.1 | 41 | 0.54 | 1.07 | NS | NS | .0038 |
| Steel counter (large—away from bed) | 50 | 1.14 | 2.51 | 50 | 1.54 | 3.08 | 50 | 0.44 | 0.67 | NS | NS | NS |
| Anesthesia machine large screen | 31 | 2.03 | 2.9 | 32 | 0.91 | 1.49 | 31 | 1.97 | 2.97 | NS | NS | NS |
| Vent monitor | 15 | 3.87 | 2.59 | 15 | 3.4 | 3.7 | 15 | 5.67 | 11.7 | NS | NS | NS |
| Anesthesia machine drawer | 20 | 5.85 | 20.1 | 21 | 3.95 | 11.5 | 20 | 1.1 | 1.94 | NS | NS | NS |
| Small computer desk | 31 | 11.6 | 8.72 | 29 | 11.6 | 14.2 | 30 | 9.3 | 13.3 | NS | NS | .0219 |
| Anesthesia steel counter | 29 | 1.66 | 2.04 | 30 | 2.53 | 4.3 | 30 | 8.77 | 29.4 | NS | NS | NS |
| All sites for aerobes | 510 | 10.1 | 23.3 | 506 | 14.7 | 34.2 | 504 | 6.33 | 17.4 | NS | <.0001 | <.0001 |
| All sites for MRSA | 510 | 0.04 | 0.38 | 506 | 0.66 | 7.08 | 504 | 0.08 | 0.93 | .0002 | .0006 | NS |

Abbreviations: CFU, colony-forming units; MRSA, methicillin-resistant *Staphylococcus aureus*; NS, not significant; SD, standard deviation.

before cleaning/disinfection (Table 1). Thirty-three percent of environmental samples after cleaning/disinfection (164 of 504) were not visually cleaned when environmental sampling was performed. The mean CFU per Rodac plate in OR sites cleaned visually after cleaning/disinfection was significantly reduced compared with those before cleaning/disinfection (4.2 vs 15.2 for aerobes, $P < .0001$; 0.11 vs 0.96 for MRSA, $P = .001$), but not in sites not cleaned visually (10.8 vs 13.7 for aerobes, $P > .05$; 0.01 vs 0.02 for MRSA, $P > .05$).

Multidrug-resistant pathogens other than MRSA (ie, VRE, CRE, *C difficile*) were not detected in any of 1520 environmental OR samples. Mean CFU of MRSA per Rodac plate was 0.04 before patient arrival, 0.66 after surgery but before cleaning/disinfection, and 0.08 after cleaning/disinfection (Table 1). The mean MRSA in ORs was significantly reduced after cleaning/disinfection, compared with that after surgery but before cleaning/disinfection ($P = .0006$). The total CFU of MRSA before cleaning/disinfection (N = 332) was reduced by 88% after cleaning/disinfection (N = 40). At least 1 CFU of MRSA per Rodac plate were identified in 3.1% of all environmental sites (47 of 1520). More importantly, of the sites where MRSA were identified, 87% was derived from floors (41 of 47), and 19% was found even after cleaning/disinfection (9 of 47, 8 from floors, and 1 from pyxis touchscreen). Pulsed-field gel electrophoresis relatedness of clinical and environmental MRSA isolates from ORs was determined (Table 2). There were examples of environmental contamination of the ORs with MRSA. It is notable that the A2/B2 MRSA strain was identified in different environmental sites (eg, floor, computer desk, counter) in various rooms (eg, OR2, OR10, OR16) even after cleaning/disinfection and was present both before patient surgery and after cleaning in only 1 case (Patient 4). Two cases were indistinguishable between clinical (2 of 9, 22%) and environmental (2 of 28, 7%) MRSA isolates after surgery but before cleaning/disinfection (ie, H, J), but none of environmental isolates before patient arrival or after cleaning/disinfection was indistinguishable from clinical isolates.

## DISCUSSION

Bacterial contamination of intraoperative anesthesia work environment can contribute to transmission of healthcare-associated pathogens, postoperative infections, and increased mortality in surgical patients [8]. Some surgeons (eg, orthopedists) seem reluctant to use ORs where the preceding patient was on contact precautions for colonization/infection with an MDR pathogen for fear that the environment would be contaminated and put their patients at risk for the previous patient's pathogen. Our study revealed substantial microbial burden in the ORs before cleaning/disinfection, but the low concordance of PFGE-identical MRSA strains between clinical and environmental isolates before cleaning/disinfection suggested pre-existing contamination as noted in environmental samples before patient arrival. Several MRSA strains were endemic or transferred to different environmental sites in other ORs and were

**Table 2. PFGE Relatedness Between Clinical MRSA Isolates From Patients Receiving Surgery and Environmental MRSA Isolates From Operating Rooms[a]**

| | | PFGE Relatedness | | | | | |
|---|---|---|---|---|---|---|---|
| Surgical Patient | Contact Isolation Organism | Clinical Isolate | Environmental Isolate Before Patient Surgery | Environmental Isolate After Surgery Before Cleaning | Environmental Isolate After Cleaning | Environmental Site | Operating Room |
| Pt2 | MRSA | A | | B | | Floor (near OR bed) | OR32 |
| | | | | B, B | | Floor (far door) | |
| Pt3 | MRSA | A1/B1 | | A2/B2, C | | Floor (far door) | OR2 |
| | | | | A2/B2 | | Computer desk | |
| Pt4 | MRSA, CRE | E | A2/B2 | D | | Pyxis counter | OR10 |
| | | | | A2/B2, A2/B2, A2/B2 | A2/B2 | Floor (near OR bed) | |
| | | | A2/B2, A2B2 | A2/B2, A2/B2, A2/B2, A2/B2, A2/B2, A2/B2, A2/B2 | A2/B2, A2/B2, A2/B2 | Floor (far door) | |
| Pt5 | MRSA | F | | G1, G | | Floor (near OR bed) | OR29 |
| | | | G | | | Floor (far door) | |
| Pt6 | MRSA | H | | H | | Blue stool | OR16 |
| | | | A2/B2, A2/B2, A2/B2 | F1, I, A2/B2 | | Floor (far door) | |
| Pt7 | MRSA, CRE | Jp | | J | | Floor (far door) | OR9 |
| | | | | J1 | | Steel counter | |
| Pt8 | MRSA | Jp | | | F2 | Floor (near OR bed) | OR2 |
| | | | | F2 | A2/B2 | Floor (far door) | |
| Pt9 | MRSA | K | F2 | A2/B2, A2/B2 | A2/B2 | Floor (far door) | OR2 |
| Pt10 | MRSA | J | Fp | | | Floor (far door) | OR9 |

Abbreviations: MRSA, methicillin-resistant *Staphylococcus aureus*; OR, operating room; PFGE, pulsed-field gel electrophoresis; Pt, patient.

[a]The number means possibly related to a strain of the uppercase letter; eg, J1 is possibly related to J. Bold underlined uppercase letters mean indistinguishable between clinical and environmental isolates. The lowercase letter "p" means probably related to a strain of the uppercase letter; eg, Jp is probably related to J.

present in the ORs even after cleaning/disinfection. The PFGE-identical MRSA strains remained in the ORs partially because environmental sites were inadequately cleaned and/or disinfected. There were evidences of clinical MRSA remaining in the ORs before cleaning/disinfection, but none of these examples were after cleaning/disinfection, which supports not excluding the use of ORs based on the presence of an MDR pathogen for the previous patient.

Deshpande et al [9] described isolation room floors frequently contaminated with healthcare-associated pathogens and potential transfer of these pathogens to hands via contact with medical equipment on the floor. Our study results also suggest that OR floors could be a reservoir of MDR healthcare-associated pathogens, demonstrating the importance of cleaning and/or disinfection of floors. According to the Association of periOperative Registered Nurses guideline [3], floors in perioperative settings should be considered contaminated at all times and should be cleaned and/or disinfected after each surgical procedure if soiled or potentially soiled.

## CONCLUSIONS

In conclusion, our study demonstrated that the environmental cleaning and/or disinfection significantly decreased the contamination on environmental surfaces in the OR where patients with confirmed MDR colonization or infection on contact precautions received surgery but some MRSA remained. The presence of MRSA highlights the importance of meticulous cleaning and disinfection to reduce the risk of surgical site infections via the contaminated environment, although this study was conducted in a single-center with small population and the clinical relevance of perioperative environmental contamination with regard to surgical site infections remains to be established.


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