http://www.cdc.gov/nhsn/acute-care-hospital/index.html. Accessed January 20, 2014.

5. Anderson DJ, Kirkland KB, Kaye KS, et al. Underresourced hospital infection control and prevention programs: penny wise, pound foolish? *Infect Control Hosp Epidemiol* 2007;28:767–773.

6. Weber DJ, Brown VM, Sickbert-Bennett EE, Rutala WA. Sustained and prolonged reduction in central line–associated bloodstream infections as a result of multiple interventions. *Infect Control Hosp Epidemiol* 2010;31:875–877.

7. Marschall J, Mermel LA, Classen D, et al. Strategies to prevent central line–associated bloodstream infections in acute care hospitals. *Infect Control Hosp Epidemiol* 2008;29(suppl 1):S22–S30.

8. King B, Schulman CI, Pepe A, Pappas P, Varas R, Namias N. Timing of central venous catheter exchange and frequency of bacteremia in burn patients. *J Burn Care Res* 2007;28:859–860.

9. Sood G, Heath D, Adams K, et al. Survey of central line–associated bloodstream infection prevention practices across American Burn Association–certified adult burn units. *Infect Control Hosp Epidemiol* 2013;34:439–440.

10. Harris AD, Pineles L, Belton B et al. Universal glove and gown use and acquisition of antibiotic-resistant bacteria in the ICU: a randomized trial. *JAMA* 2013;310:1571–1580.

Microbial Contamination on Used Surgical Instruments

Surgical instruments are considered critical items because they enter sterile body tissues or the vascular system, and if contaminated with any microorganism, including bacterial spores, this could result in an infection. Critical items are generally sterilized by steam sterilization if heat resistant. If heat sensitive, the object may be sterilized with ethylene oxide, hydrogen peroxide gas plasma, or vaporized hydrogen peroxide. However, these technologies have a lower margin of safety than steam sterilization.[1] Because the level of microbial contamination of the object to be sterilized plays a critical role in determining the efficacy of the sterilization process, we evaluated the microbial load on used surgical instruments before cleaning and sterilization.

This study was conducted at the University of North Carolina Health Care, an 810-bed medical center. A variety of stainless steel surgical instruments were chosen, including Mayo straight scissors, forceps (eg, curved tip, large, and Debakey), rake, scissors (eg, curved), small-prong fork, small-pronged clamps, hemostats, knife handles, retractor, and needle holders. These instruments were all used in our operating rooms. After use in surgical procedures, the instruments were transported in peel packs to the hospital epidemiology laboratory and aseptically fully immersed in trypticase soy broth (Remel). The broth and instruments were agitated on a shaker at 150 rpm. After 30 minutes of agitation, two 500-μL samples were removed and plated onto sheep blood agar (SBA; Remel). The remaining broth was filtered through a disposable 0.45-μm cellulosic membrane filter unit (MSI Savur). Any

colonies in the 500-μL samples were identified, and the total number on the device was calculated by multiplying by the volume of fluid. Any colonies on the SBA or filter were enumerated and identified using standard microbiological techniques.

Fifty surgical instruments were obtained from 12 operations. Less than 10 colony-forming units (CFUs) per device were recovered from 58% of the used instruments (Table 1). Eleven to 100 CFU were recovered from 20% of the used instruments, and greater than 100 CFU (median, 207 CFU) were recovered from 14% of the instruments. In 4 cases (8%), greater than 1,000 CFU were recovered from the instruments (ie, 2.4×10^3 *Bacillus cereus* on forceps; 4.4×10^3 *B. cereus* on a rake; 1.94×10^4 on a pronged clamp (containing 5.4×10^3 coagulase-negative *Staphylococcus*, 6.6×10^3 α-*Streptococcus*, 5.8×10^3 *Streptococcus pneumoniae*, and 1.6×10^3 *Micrococcus* species); and 4.98×10^4 on a hemostat (containing 5.4×10^3 *S. pneumoniae*, 4.4×10^4 α-*Streptococcus*). The most common contaminating organisms were coagulase-negative *Staphylococcus* species, α-*Streptococcus*, diphtheroids, *Micrococcus* species, *B. cereus, Escherichia coli*, and *Bacillus* species (Table 1).

The data revealed that the microbial load on used surgical instruments before cleaning was generally low; 58% had 10 CFU or less, and 78% had 100 CFU or less. In a study of contamination levels on used surgical instruments before

TABLE 1. Microbes Contaminating Used Surgical Instruments and Microbial Load When Submitted to Central Sterilization Services

Variable	No. (%) of instruments ($n = 50$)
Colony count, CFU	
0–10	29 (58)
11–100	10 (20)
101–1,000	7 (14)
>1,000	4 (8)
Microbe	
Coagulase-negative *Staphylococcus* species	24 (48)
α-*Streptococcus* species	13 (26)
Diphtheroids	10 (20)
Micrococcus species	10 (20)
Bacillus cereus	9 (18)
Bacillus species (not *cereus*)	5 (10)
Escherichia coli	5 (10)
Enterococcus (vancomycin susceptible)	2 (4)
Pseudomonas aeruginosa	2 (4)
Streptococcus pneumoniae	2 (4)
Enterococcus species (vancomycin resistant)	1 (2)
Pantoea species	1 (2)
Serratia marcescens	1 (2)
Staphylococcus aureus (oxacillin susceptible)	1 (2)

NOTE.   Instruments were used in a total of 12 operations. Of the 50 instruments cultured, 9 (18%) showed no growth. CFU, colony-forming unit.

cleaning, Nystrom reported that 60% of the instruments carried less than 10 CFU, 80% carried less than 100 CFU, and 90% carried less than 1,000 CFU.[2] Whether the operations were clean, clean-contaminated, contaminated, or dirty did not significantly affect the microbial load. Pinto et al[3] found that fewer microorganisms were recovered from instruments used in clean surgeries (47%) in comparison with those used in contaminated (70%) and infected (80%) surgeries. These data are similar to 3 other studies that evaluated the microbial load on surgical instruments after cleaning[4] or before and after cleaning but before sterilization.[5,6] Chan-Myers evaluated the bioburden associated with rigid lumened instruments before and after cleaning and found the bioburden associated with rigid-lumened devices after clinical use but before cleaning was relatively low (median, 132 CFU) per device.[6]

The level of microbial contamination on lumened and non-lumened surgical instruments is approximately 3 $\log_{10}$ CFU lower than that of model test systems used for evaluating sterilization systems.[6] That is, it is usually assumed that the level of microbial contamination of a medical or surgical device is 10^6 CFU. Another level of conservatism is that regulatory agencies require the inactivation of spores, which are the most difficult contamination to inactivate, rather than vegetative bacteria, which are commonly found on instruments.[4-6] Regulatory testing for sterilization validation should be robust but also clinically relevant (eg, microbial load and soil).

Decontamination of used surgical instruments is recommended for the following 2 reasons: (1) it protects the staff handling the instruments from acquiring infection in the event of a percutaneous injury, and (2) it reduces the microbial contamination on instruments as well as protein and salt before sterilization and thereby enhances the reliability of the sterilization process. Protein and salt have been shown to interfere with the sterilization processes, especially low-temperature sterilization processes.[1,7] The exact mechanism by which salt and protein protect against microbial inactivation is not understood completely, but it likely represents occlusion of microorganisms in crystalline materials and impedance of vapor or gas penetration in a microenvironment.[7] The low microbial load on used surgical instruments before cleaning likely reflects contact or use of these instruments in normally sterile body sites and fluids. In contrast, published studies on the bioburden associated with instruments used in nonsterile sites, such as flexible endoscopes (ie, colonoscopes), report much higher levels of microbial contamination ranging from 10^8 to 10^{10} CFU (internal channels).[8-10] This microbial level is due to the very high numbers of bacteria present in the human colon. Studies that have evaluated the effectiveness of washer-disinfectors commonly used to decontaminate surgical instruments (but not flexible endoscopes) are capable of removing or inactivating 10^8 CFU,[11] which far exceeds the level on used instruments.

In summary, our data suggest that properly cleaned non-lumen surgical instruments carry a low microbial load of relatively nonpathogenic microbes. In the absence of protein and salt, low-temperature sterilization technologies are likely to be effective in preventing cross-transmission of infection via nonlumened medical and surgical instruments.

William A. Rutala, PhD, MPH;[1,2]
Maria F. Gergen, MT(ASCP);[1]
David J. Weber, MD, MPH[1,2]

Affiliations: 1. Department of Hospital Epidemiology, University of North Carolina Health Care, Chapel Hill, North Carolina; 2. Division of Infectious Diseases, University of North Carolina School of Medicine, Chapel Hill, North Carolina.
Address correspondence to William A. Rutala, PhD, MPH, 2163 Bioinformatics, CB 7030 Chapel Hill, NC 27599 (brutala@unch.unc.edu).

REFERENCES

1. Alfa MJ, DeGagne P, Olson N, Puchalski T. Comparison of ion plasma, vaporized hydrogen peroxide and 100% ethylene oxide sterilizers to the 12/88 ethylene oxide gas sterilizer. *Infect Control Hosp Epidemiol* 1996;17:92–100.
2. Nystrom B. Disinfection of surgical instruments. *J Hosp Infect* 1981;2:363–368.
3. Pinto FMG, deSouza RQ, daSilva CB, Mimica LMJ, Graziano KU. Analysis of the microbial load in instruments used in orthopedic surgeries. *Am J Infect Control* 2010;38:229–233.
4. Rutala WA, Gergen MF, Jones JF, Weber DJ. Levels of microbial contamination on surgical instruments. *Am J Infect Control* 1998;26(2):143–145.
5. Chu NS, Chan-Myers H, Ghazanfari N, Antonoplos P. Levels of naturally occurring microorganisms on surgical instruments after clinical use and after washing. *Am J Infect Control* 1999; 27(4):315–319.
6. Chan-Myers H, McAlister D, Antonoplos P. Natural bioburden levels detected on rigid lumened medical devices before and after cleaning. *Am J Infect Control* 1997;25(6):471–476.
7. Jacobs P. Cleaning: principles, methods and benefits. In: Rutala WA, ed. *Disinfection, Sterilization, and Antisepsis in Healthcare.* Champlain, NY: Polyscience, 1998:165–181.
8. Chu NS, Favero M. The microbial flora of the gastrointestinal tract and the cleaning of flexible endoscopes. *Gastrointest Endosc Clin North Am* 2000;10(2):233–244.
9. Alfa MJ, Degagne P, Olson N. Worst-case soiling levels for

patient-used flexible endoscopes before and after cleaning. *Am J Infect Control* 1999;27(5):392–401.

10. Roberts CG. Studies on the bioburden on medical devices and the importance of cleaning. In: Rutala WA, ed. *Disinfection, Sterilization and Antisepsis: Principles and Practices in Healthcare Facilities*. Washington, DC: Association for Professionals in Infection Control and Epidemiology, 2001:63–69.

11. Rutala WA, Gergen MF, Weber DJ. Efficacy of a washer-disinfector in eliminating healthcare-associated pathogens from surgical instruments. *Infect Control Hosp Epidemiol* 2014;35(7):883–885.

Room Decontamination Using an Ultraviolet-C Device with Short Ultraviolet Exposure Time

Disinfection of noncritical room surfaces and equipment is normally performed by manually applying a liquid disinfectant with a cloth, wipe, or mop. Studies have shown 10%–50% of the surfaces in rooms with patients colonized or infected with *Clostridium difficile*, methicillin-resistant *Staphylococcus aureus* (MRSA), and vancomycin-resistant *Enterococcus* (VRE) are contaminated with these pathogens, and a lack of thoroughness in cleaning contaminated surfaces in such rooms (mean, 32% of surfaces and objects cleaned) has been linked to a 120% increase in risk of infection to the next occupant in that room.[1,2] These data have led to efforts to improve surface disinfection practices and the development of "no-touch" room decontamination units that avoid the problems associated with manual disinfection.[3]

Room decontamination units that use ultraviolet-C (UV-C, 254 nm) are commercially available and have been shown to effectively decontaminate surfaces in patient rooms.[4-8] The purpose of this study was to determine whether a fixed cycle-time UV-C device was effective in inactivating the test bacteria in a patient room with and without reflective coating. To better understand the effect of the reflective coating, the UV-

C intensity on surfaces of interest were directly measured using a UV-C radiometric sensor.

We investigated a single, easily transportable UV-C device (V-360+, UltraViolet Devices) that incorporates four 64-inch UV-C lamps having a total output of 1,200 W. The device's cycle time was determined by the manufacturer on the basis of the size and configuration of various-sized rooms. Measurements were performed in 2 patient rooms as described previously.[8]

Testing was performed as previously reported using *C. difficile* spores and a clinical isolate of MRSA.[8] The room decontamination times were fixed at 5 minutes for MRSA and 10 minutes for *C. difficile* spores. Following cycle completion, each Formica template was cultured, and after incubation, the colony-forming units of the test organisms on each plate were quantified.

Measurements of UV-C irradiance energy (W/cm^2) were performed using a radiometer (ILT1700 Research Radiometer, International Light Technologies) equipped with a calibrated, National Institute of Standards and Technology–traceable UV-C detector with appropriate filter and diffuser (SED240/NS254/W, International Light Technologies).

For disinfection of MRSA with a 5-minute cycle time, we observed a 3.56-$\log_{10}$ reduction without the reflective coating and 4.50-$\log_{10}$ reduction with the reflective coating. For disinfection of *C. difficile* spores with a 10-minute cycle time, we observed a 2.78-$\log_{10}$ reduction without the reflective coating and 3.05-$\log_{10}$ reduction with the reflective coating (Table 1). The most significant improvements when a reflective wall coating was used were seen on indirect surfaces, where a 1.47-$\log_{10}$ reduction increase was observed for MRSA and a 0.81-$\log_{10}$ reduction increase was observed for *C. difficile* spores. Measurements of UV-C irradiance were roughly 1×10^{-3} W/cm^2 for direct surfaces in both rooms. For indirect surfaces, however, the reflective coating increased the UV-C irradiance tenfold from 3.7×10^{-6} to 4.5×10^{-5} (Figure 1).

These results confirm earlier findings that UV-C devices can effectively disinfect patient rooms. This unit achieved a total 3.56-$\log_{10}$ reduction (4.10 direct, 2.74 indirect) for MRSA in 5 minutes and a total 2.78-$\log_{10}$ reduction (3.35

TABLE 1. Ultraviolet-C Decontamination of Formica Surfaces in Patient Rooms That Were Experimentally Contaminated with Methicillin-Resistant *Staphylococcus aureus* (MRSA) and *Clostridium difficile* Spores with and without a Reflective Coating on Walls

Variable	MRSA		C. difficile	
	Without coating	With coating	Without coating	With coating
Cycle time, minutes	5	5	10	10
Direct surfaces	4.10 (3.88–4.32); 30	4.68 (4.61–4.76); 30	3.35 (3.14–3.55); 30	3.34 (3.10–3.59); 30
Indirect surfaces	2.74 (2.53–2.94); 20	4.21 (4.00–4.42); 20	1.80 (1.36–2.24); 20	2.61 (2.24–2.97); 20
Overall	3.56 (3.31–3.80); 50	4.50 (4.38–4.61); 50	2.78 (2.48–3.07); 50	3.05 (2.82–3.28); 50

NOTE. Data are mean $\log_{10}$ reduction in colony-forming units (95% confidence interval) and no. of samples, unless otherwise indicated. Patient room is 130 square feet (12.077 m^2) in area. Confidence intervals were calculated based on a Poisson distribution.