Emergency Department Ultrasonographic Probe Contamination and Experimental Model of Probe Disinfection

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Study objective: We evaluate the frequency of emergency department (ED) ultrasonographic probe contamination and the bacterial species involved and evaluate probe cleaning and disinfection methods.

Methods: This was a 3-part observational cross-sectional study. Surveillance cultures were taken of linear and curvilinear probes on 3 ultrasonographic machines between patient encounters. Cultures of uncovered probes were taken immediately after scanning of skin and soft tissue infections. After experimental probe contamination with methicillin-resistant \textit{Staphylococcus aureus} (MRSA), we assessed 3-step disinfection by sequential cleaning with a dry towel, saline solution–moistened towel, and quaternary ammonia germicidal wipe and 1-step disinfection by germicidal wipe alone. Cultures were obtained by applying the probe to a blood agar plate.

Results: In part 1, of 164 surveillance cultures obtained from 6 probes on 29 sampling days during 11 months, 111 (67%; 95% confidence interval [CI] 60% to 74%) grew normal skin flora or environmental flora, 52 had no growth (32%; 95% CI 25% to 39%), and 2 (1.2%; 95% CI 0.3% to 4.3%) grew a clinically important pathogen. In part 2, 14 of 20 (70%; 95% CI 48% to 85%) cultures taken after skin and soft tissue infection scanning produced heavy growth of a clinically important pathogen, including 13 \textit{S aureus} (5 MRSA). In part 3, cleaning with a dry and moist towel reduced but did not eliminate MRSA. The germicidal wipe step resulted in no growth in 15 of 15 (100%; 95% CI 80% to 100%) cultures in 3-step disinfection and in 9 of 10 (90%; 95% CI 60% to 98%) when used alone.

Conclusion: Skin and environmental flora are commonly present on ultrasonographic probes between patient encounters in our ED; however, clinically important pathogens are uncommon. \textit{S aureus} (including MRSA) frequently contaminates uncovered probes during skin and soft tissue infection scanning, but in an experimental model, MRSA appears to be reliably removed by a quaternary ammonia germicidal wipe if the probe is partially cleaned first. [Ann Emerg Med. 2011;58:56-63.]

Please see page 57 for the Editor’s Capsule Summary of this article.

INTRODUCTION

Background

\textit{Staphylococcus aureus}, particularly methicillin-resistant \textit{S aureus} (MRSA), causes the majority of skin soft tissue infections observed in many US emergency departments (EDs), and the incidence of these infections has increased during the last decade.\textsuperscript{1,2} MRSA is also a leading cause of invasive nosocomial infections.\textsuperscript{3} It is not fully understood how MRSA is transmitted between patients, but \textit{S aureus} is known to survive readily on fomite surfaces, and colonized fomites have been linked to hospital- and community-onset MRSA outbreaks.\textsuperscript{4,5} MRSA has been recovered from ED work surfaces and curtains.\textsuperscript{4,5}

Meanwhile, bedside ultrasonographic machines have become nearly ubiquitous in US EDs, and ultrasonographic training is a core competency in emergency medicine residencies. The utility of ultrasonography to assess skin and soft tissue infections is well established.\textsuperscript{7} In busy academic EDs like ours, ultrasonographic probes may contact several patients in an hour, and skin and soft tissue infection scanning is common. Thus, it seems possible that ultrasonographic probes could transmit pathogens such as MRSA between patients in the ED.

There are a number of studies showing that \textit{S aureus}, including MRSA, and other nosocomial pathogens can be recovered from ultrasonographic probes during routine clinical use in the hospital.\textsuperscript{10-14} A single study has linked actual infection—an outbreak of methicillin-susceptible \textit{S aureus} skin infections in neonates—to contaminated ultrasonographic gel.\textsuperscript{15} However, few studies have been conducted since the emergence
Editor's Capsule Summary

What is already known on this topic
Pathogens may be inadvertently transmitted among patients by medical devices.

What question this study addressed
This 3-part study examined the prevalence of bacterial contamination on emergency department ultrasonographic probes, generally and after contact with soft tissue infections, and evaluated cleaning and disinfection methods.

What this study adds to our knowledge
Bacterial contamination was common, particularly after contact with soft tissue infections (14/20 cultures grew pathogens, predominantly Staphylococcus aureus). In the disinfection experiment, dry and moist towel cleaning followed by germicidal wipe resulted in no growth in 15 of 15 cultures; germicidal wipe alone eliminated growth in 9 of 10 cultures.

How this is relevant to clinical practice
Clinicians should assume that ultrasonographic probes are contaminated and should disinfect them or use probe covers.

of community-associated MRSA, and to our knowledge no study of this issue has been conducted specifically in the ED setting or focused on skin and soft tissue infection scanning.

Finally, there is little evidence on the issue of ultrasonographic probe disinfection in the ED. Recommendations about nonendocavitary probes are limited and generally specify low-level disinfection. It is unclear whether recommended disinfection methods, or the kind of routine cleaning and disinfection that actually occurs in busy EDs, are sufficient to eliminate probe contamination in the setting of frequent skin and soft tissue infection scanning. Moreover, studies comparing ultrasonographic probe cleaning and low-level disinfection methods, for example, wiping with a dry paper towel versus a germicidal wipe, have produced conflicting results.

Importance
Data on ED ultrasonographic probe contamination and on cleaning and disinfection methods are needed to develop evidence-based disinfection guidelines.

Goals of This Investigation
This was a 3-part study exploring the issue of ultrasonographic probe bacterial contamination and disinfection. The goals were to evaluate probe microbial contamination between patient encounters during routine use, evaluate contamination specifically after skin and soft tissue infection scanning, and evaluate a low-level disinfection method after experimental probe contamination with MRSA.

MATERIALS AND METHODS

Study Design
This was a 3-part, observational, cross-sectional study.

Setting
The study was conducted in the ED of an urban county teaching hospital located in Oakland, CA, with an emergency medicine residency program and an emergency ultrasound fellowship. The annual ED census is approximately 90,000 visits. The study took place between August 2009 and July 2010. It was approved by the medical center institutional review board. The probe disinfection experiment was conducted in our hospital’s clinical microbiology laboratory.

During the study period, the ED had in use 3 ultrasonographic machines (M-Turbo, Micromaxx, and S-FAST; SonoSite, Bothell, WA), each with at least 1 linear and 1 curvilinear probe. There were 384 skin and soft tissue infection scans recorded in ultrasonographic video log during the 11 months of the study, although the number performed was certainly higher. Our department ultrasonographic policy specifies to disinfect nonendocavitary ultrasonographic probes with a disposable germicidal wipe after each use. The policy does not specify to clean first with a towel, although this is often done (to remove ultrasonographic gel). Sterile probe covers are required only for endocavitary scans and ultrasonographically guided central line placement; probe covers are inconsistently used for skin and soft tissue infection scans.

Sample Selection and Procedures
In part 1, the surveillance part of the study, an investigator conducted an ED sweep and obtained cultures of both the curved and linear probes on each of the 3 ultrasonographic machines. The probe faces were touched to blood agar culture plates. Sweeps occurred at times convenient to the investigators throughout the 11-month study period, though we attempted to take samples during all 3 ED shifts and not to overrepresent ultrasonographic fellow scanning shifts (when frequent probe cleaning was presumed to occur). Samples were taken between patient encounters, when machines were sitting idle. There were 6 cultures per sweep, unless a machine was in active use or being serviced. Although there was no formal blinding, investigators usually were unaware of how or by whom the machine had been used last or whether probes had been cleaned. Staff was unaware when sampling would occur and generally unaware that the study was being conducted.

In part 2, investigators identified a convenience sample of patients who were undergoing skin and soft tissue infection scanning as part of routine clinical care. Investigators monitored the electronic patient locator board for skin and soft tissue
infection cases and asked the providers whether they planned to conduct ultrasonography. Investigators either performed the scan for the provider or repeated it. Basic features of the skin and soft tissue infection were recorded prospectively on a data sheet.

To eliminate any bacteria on the probe from a previous patient, the linear probe was first cleaned with a germicidal wipe and then wiped with a sterile saline solution–moistened gauze towel to remove residual germicide. Plate and broth cultures were obtained immediately before and after scanning the infection site, without wiping off the ultrasonographic gel. During the scan, the probe face generally touched any fluctuant or necrotic areas. Plate cultures were obtained as described above. Broth cultures were obtained by applying a sterile saline solution–moistened Dacron swab to the probe face and then breaking it off in a vial containing broth culture medium. We decided a priori to include broth cultures in this part of the study to maximize sensitivity for small numbers of contaminating bacteria. (Because they are expensive and time consuming, we did not use broth cultures in the larger surveillance part.)

In part 3, the probe disinfection experiment we used a clinical MRSA isolate that was susceptible to trimethoprim–sulfamethoxazole, clindamycin, and tetracycline. The isolate underwent genotyping with methods described elsewhere and was found to be spa type t121 and to contain the Panton–Valentine leukocidin gene and the arginine catabolic mobile element, which together identify it as a USA 300 strain. Linear ultrasonographic probes were inoculated with this MRSA isolate by immersing the probe face in a broth of $10^{10-11}$ bacteria/mL. This bacterial concentration was chosen because it approximates the upper limit of that found in skin abscesses.

In a 3-step cleaning and disinfection protocol, sequential plate cultures were obtained after each of the following steps: bacterial inoculation, wiping with a dry gauze towel, wiping with a sterile saline solution–moistened gauze towel, and wiping with a quaternary ammonia germicidal wipe (Super Sani-Cloth; Professional Disposables International, Inc, Orangeburg, NY). The probe was not reinoculated or washed off by other means between steps. Plate cultures were obtained as described above. The probe was then washed with soap and water (to remove residual germicide) and the protocol was repeated for 15 runs. A separate 1-step disinfection protocol, in which the dry and wet towel cleaning steps were omitted, was repeated for 10 runs. The 1-step protocol was designed to test the germicidal wipe without the advantage of precleaning.

**Outcome Measures**

In the surveillance part of the study, the outcome measures were the prevalence of microbial contamination on ultrasonographic probes between patient encounters, and the species involved.

Our a priori definition of a clinically important bacterial isolate (in parts 1 and 2) was a human pathogen that could be transmitted from patient to patient through skin contact (not by respiratory or fecal–oral route), such as *Staphylococcus aureus* or β-hemolytic streptococci. We defined as normal skin flora *Corinebacterium* species, viridans group streptococci, nonhemolytic *Staphylococcus* species, and *Micrococcus* species. *Bacillus* and *Aspergillus* species were considered environmental flora. In reporting these culture results, ie, post hoc, we stratified the number of colonies as less than 10, 10 to 100, and greater than 100 to convey whether growth was light, moderate, or heavy, respectively.

In the skin and soft tissue infection scanning part of the study, outcome measures were the rate of probe contamination with clinically important bacteria immediately after skin and soft tissue infection scanning, and the species involved.

In the probe disinfection experiment, the outcome measure was the ability of cleaning and disinfection methods to reduce the number of colony-forming units of, or to eliminate, MRSA from the ultrasonographic probe face. The number of colonies growing on each plate at 24 hours was estimated by visual inspection. Semiquantitative culture results were reported, using the following ranges that had been specified a priori: no growth, 1 to 100 colonies, 100 to 500 colonies, 500 to 1,000 colonies, colonies too numerous to count.

Five percent sheep blood trypticase soy agar solid media (plates) and thioglycollate broth were incubated at 35°C (95°F) in an ambient air incubator for 48 hours before final evaluation. In part 2, if no growth was observed on the plates, broth was examined for evidence of growth and, if present, subcultured onto solid media. Recovered microorganisms (bacteria and fungi) were identified and antimicrobial susceptibilities were determined with standard clinical microbiology methods. Culture results were recorded by hand on a data collection sheet. The microbiologist investigator was not blinded to the study hypothesis or, in part 3, which step in the experiment the cultures originated.

**Primary Data Analysis**

Ninety-five percent confidence intervals (CIs) around proportions are presented. CIs were calculated with the online VassarStats Web site for statistical computation (available at http://faculty.vassar.edu/lowry/vassarstats.html).

**RESULTS**

We performed 29 sweeps, during which we collected 164 surveillance cultures (58 during a day shift, 90 during a swing shift, and 16 during a night shift). Surveillance culture results are listed in Table 1. There were 111 (67%; 95% CI 60% to 74%) cultures that grew normal skin flora or environmental flora. Of 8 that produced heavy growth of skin flora, 7 were from a curvilinear probe. Positive culture results were otherwise distributed fairly evenly between linear and curvilinear probes. Only 2 (1.2%; 95% CI 0.3% to 4.3%) surveillance culture isolates met our definition of clinically important. One curvilinear probe grew 4 colonies of *Acinetobacter baumannii*, and 1 linear probe grew 3 colonies of *Acinetobacter lwoffi*.

All 20 cultures taken immediately before scanning skin and soft tissue infections either produced no growth or light growth...
(fewer than 10 colonies) of normal skin flora. Results of cultures taken after scanning, along with features of the infections, are listed in Table 2. All but 1 produced heavy growth (greater than 100 colonies). Fourteen of 20 isolates (70%; 95% CI 48% to 85%) met our definition of a clinically important pathogen, including 5 MRSA. Among the 18 infections in which a description was recorded, only 5 had no signs of purulence, whereas 9 were described as fluctuant but closed, and 7 had drainage or necrosis.

Results of the probe cleaning experiment are presented in Table 3. Probe inoculation with MRSA was successful, producing near-confluent growth on the plate (in the shape of the probe face) in each run. In the 3-step protocol, simply wiping with a dry gauze towel reduced subsequent growth to some extent in 11 of 15 runs. Wiping with moistened gauze consistently further reduced the number of colonies that grew and appeared to completely disinfect the probe (no subsequent growth) in one instance. Wiping with a germicidal wipe disinfect ed the probe in all 15 runs (100%; 95% CI 80% to 100%). In the 1-step protocol, wiping with the germicide alone disinfect ed the probe in 9 of 10 runs (90%; 95% CI 60% to 98%). Overall, wiping with a germicidal wipe disinfect ed the probe in 24 of 25 runs (96%; 95% CI 81% to 99%).

LIMITATIONS

This study has a number of limitations. The surveillance data (part 1) may not be generalizable to other EDs that differ substantially from ours in terms of case mix, ultrasonographic use, or probe cleaning protocol. Probe cleaning might vary in departments without a residency or ultrasonographic fellowship.

There may have been selection bias in the skin and soft tissue infection scanning portion of the study (part 2) in that infections without an obvious purulent collection—in which ultrasonographic evaluation is actually most useful—appear to be underrepresented. Sampling immediately after skin and soft tissue infection scanning, before wiping off the coupling ultrasonographic gel, could have led to an overestimate of contamination, and it is possible that some clinically important bacterial isolates came from the gel rather than the patient’s skin and soft tissue infection.

In part 3, the small number of observations resulted in wide CIs around proportions, limiting the strength of our conclusion about cleaning and disinfection methods. The single positive culture result after a germicidal wipe step could have been caused by a flaw in the experimental protocol itself—which involved a thin, highly concentrated bacterial broth, many glove changes, and a cramped laboratory bench—as opposed to actual failure of disinfection. We did not use ultrasonographic gel and therefore did not simulate clinical conditions as well as we might have. Sequential cleaning that included wiping with a wet towel before germicide also deviates from usual clinical practice and may have led to overestimating germicide efficacy. We tested only a single type of germicidal wipe, whereas comparison with other low-level disinfectant compounds or application with a spray bottle would have been of interest.
Our finding that more than half of cultures grew normal skin flora is similar to the results of the British multicenter study. It is unclear whether the presence of normal skin flora reflects host defenses. These results are similar to the findings of a British multicenter, hospital-wide study in which probes were contaminated with pathogenic bacteria. Only 2 isolates met our definition of clinically important pathogen, 1 methicillin-susceptible Staphylococcus aureus and 1 A lwofi. A lwofi is actually of unclear significance because Acinetobacter species are common environmental isolates and skin colonizers that generally cause nosocomial infections in patients with impaired host defenses. These results are similar to the findings of a British multicenter, hospital-wide study in which probes were typically cleaned with a dry towel only but probe covers were used when scanning nonintact skin. Our results differ, however, from both a Nigerian study done in the inpatient and outpatient setting and a British study limited to vascular surgery wards, which found that when ultrasonographic probes were cultured at random, 10% to 40% were contaminated with S aureus.

Our finding that more than half of cultures grew normal skin flora is similar to the results of the British multicenter study. It is unclear whether the presence of normal skin flora reflects failure to clean the probe after its last use, partial cleaning with a towel only, or difficulty completely eliminating these bacteria despite cleaning with a germicidal wipe. Skin flora also could have come from individuals or sources other than patients who had recently been scanned. Possibilities include contamination from the sonographer’s hands or contaminated gloves, from the investigator’s hands, from ultrasonographic gel or the gel container, and spread from other colonized parts of the machine, such as the cord attached to the probe or the keyboard. These modes of contamination, because they can occur between patient encounters, argue for the practice of disinfecting the probe immediately before scanning. Isolation of environmental flora further supports the notion that probe contamination can occur from sources aside from patient’s skin or while the probe is not in use.

These data suggest that in our ED, despite a policy specifying to do so, cleaning with a germicidal wipe is not always done after relatively clean applications, such as abdominal scans. This is supported by the finding that 7 of 8 cultures with heavy growth of normal skin flora were from a curvilinear probe. On the other hand, in light of the results of part 2 (heavy contamination after skin and soft tissue infection scanning), the data suggest that disinfection is conducted consistently after skin and soft tissue infection scans. Although probe disinfection practices in our busy ED may at times be lax, disinfection appears to be well targeted and overall sufficient to keep contamination with pathogenic bacteria very low.

In part 2 of the study, we found that immediately after scanning skin and soft tissue infections, many of which were purulent, probes were often heavily contaminated with bacteria. Broth cultures proved unnecessary because all but 1 probe produced heavy, often confluent growth on the culture plate. As expected, S aureus predominated and MRSA was isolated from 25% of probes. However, MRSA accounted for only 39% (95% CI 18% to 65%) of S aureus isolates, whereas in 2004, MRSA accounted for 75% to 78% of S aureus skin and soft tissue infections in US EDs, including ours. The comparatively low MRSA prevalence in this study may be a statistical phenomenon caused by the small sample size, or it might reflect a recent decrease in MRSA prevalence in our population, as would be expected past the peak of an epidemic. That heavy contamination occurred in some cases that were not...
identified as fluctuant or necrotic suggests that even clinically nonpurulent infections may pose a significant risk for contamination of ultrasonographic probes and other fomites with pathogenic bacteria.

It seems likely that, if not meticulously disinfected after skin and soft tissue infection scanning, these uncovered probes could transmit bacteria such as MRSA to other patients either directly or by contaminating health care providers’ hands. *S. aureus* can survive on and colonize fomite surfaces, and such reservoirs may be particularly important in community-associated MRSA transmission.8 Outbreaks of community-associated MRSA furunculosis and soft tissue abscesses are thought to have occurred from contaminated fomites coming in contact with breaks in the skin.6,23

In part 3 of the study, we chose to inoculate probes with USA 300 MRSA because this strain is currently the most common cause of skin and soft tissue infections,1 can survive on plastic fomites,24 and how it spreads between individuals is not well understood.8 Also, *S. aureus* was the most common pathogen isolated in previous studies of probe contamination.10-12 We do not know how the simple bacterial broth we used might differ, in terms of how easily it can be removed, from the mixture of ultrasonographic gel, blood, and other organic material that is encountered in the clinical setting. We tested simply wiping with a dry gauze towel as a cleaning method because previous studies have suggested that cleaning with a dry towel may be sufficient,10,13,16 and it was all that was used in more than 45% of surveyed hospitals in England in 2003.25

We found, as did Mullaney et al,12 that wiping with a dry towel alone and dry towel followed by moist towel is insufficient to completely disinfect heavily contaminated probes. However, these methods did reduce contamination, and performing this kind of cleaning before applying disinfectant to remove organic material and reduce bacterial counts is an important principle in medical device disinfection.17 In contrast, wiping with a quaternary ammonia germicidal wipe disinfected 9 of the 10 heavily contaminated probes, as well as all 15 that had been partially cleaned first. The lower 95% CI for successful disinfection among all 25 is only 80%, however, which leaves some question about the effectiveness of the quaternary ammonia wipe, particularly if there is heavy contamination or if the probe is not cleaned with a towel first.

Placing our findings into the context of current medical device disinfection guidelines is not straightforward. According to Centers for Disease Control and Prevention (CDC), ultrasonographic probes are considered semicritical devices if they contact mucosal surfaces or nonintact skin (endocavitary ultrasonographic probes) and noncritical if contact is limited to intact skin (abdominal and cardiac probes).17 Semicritical devices require high-level disinfection, which involves cleaning followed by prolonged exposure to high-level disinfectant compounds such as glutaraldehyde (Cydex). Noncritical devices require low-level disinfection, involving brief exposure to certain disinfectants, such as the quaternary ammonia product used in our study. The problem is that in the ED, high-frequency linear probes are used for skin and soft tissue infection scanning, ultrasonographically guided central line placement, ultrasonographically guided nerve blocks, pneumothorax evaluation in trauma, and other applications. Thus, their use spans the semicritical and noncritical categories. Subjecting these workhorse probes to the same high-level disinfection as endocavitary probes after each use is not feasible. The American Institute of Ultrasound in Medicine recommends that nonendocavitary probes be cleaned with quaternary ammonium wipes or sprays after each use, presumably regardless of the application.18 Guidelines are not clear, however, on how to handle otherwise noncritical devices after use on infected skin. It has been suggested that disinfection methods be tailored to the circumstances of the scan, with additional measures taken after contact with blood or other body fluids.10,18

In essence, in part 3 of our study, we tested the efficacy of a typical low-level disinfection method in an MRSA ultrasonographic probe contamination model. We also provide evidence in part 1 about the effectiveness of this method when used in an unstructured clinical setting in which skin and soft tissue infection scanning is common. (In part 2, we showed that skin and soft tissue infection scanning causes at least momentary heavy contamination with skin pathogens.) Although not definitive, our results support the practice of cleaning with a towel, followed by wiping with a quaternary ammonium compound. This method of low-level disinfection appears effective even in the setting of skin and soft tissue infection scanning, is feasible, and is acceptable to ultrasonographic machine manufacturers. Whether an abbreviated method, such as simply wiping with a disinfectant, is sufficient after scanning uninfected intact skin, as in the case of most abdominal scans, is debatable.

There are numerous other low-level disinfection methods and strategies to reduce contamination that should be considered. Disinfectant compounds that tend to be acceptable to ultrasonographic manufacturers include sodium hypochlorite (bleach), hydrogen peroxide, and glutaraldehyde, some of which are available in spray form.26 The CDC does not recommend soap and water alone, and measures that require removing the probe from the machine are generally not practical for high-use ED probes. Wiping with a disinfectant immediately before performing all scans (as well as afterwards) is feasible and addresses the possibility of contamination occurring between scans, from the environment or a provider’s hands. Probe covers should be required in the presence of blood, drainage, or a skin opening and—in light of our findings showing heavy bacterial contamination even in closed skin and soft tissue infections—they may be advisable for all skin and soft tissue infection scans.

In addition, attention to “standard precautions” as defined by the CDC is crucial.27 These state to wash hands after every patient encounter, which includes ultrasonographic scanning of any kind, and to wear gloves when in contact with nonintact skin or body fluids, which applies to skin and soft tissue...
infection scanning. The number of colony-forming units of *S. aureus* found on health care providers’ hands commonly equals or exceeds the number we found on ultrasonographic probes in the surveillance and skin and soft tissue infection parts of this study,28 a fact that lends perspective to this discussion. Standard precautions can logically be extended from hands to ultrasonographic probes, further supporting the requirement that probe covers be used, in addition to disinfection, in the setting of nonintact skin or body fluids.

Finally, although our study examined the process of contamination from infected skin to ultrasonographic probe, another clinically important step is transmission from contaminated fomite to the next patient or to a provider’s hand.7,8,24 This issue may be particularly relevant to the kinds of pathogens picked up after skin and soft tissue infection scanning and the number of residual bacteria typically left on the probe face after failure to completely disinfect it. Fewer than 10 MRSA bacteria on an ultrasonographic probe may not present a sufficient inoculum for acquisition or initiation of infection, whereas 10 to 100 bacteria may, particularly if the following patient has compromised skin integrity.7

Future studies might conduct surveillance in a variety of ED settings and use broth cultures because numbers of pathogenic bacteria might be quite low. Studies of disinfection methods should incorporate ultrasonographic gel, vary the concentration of bacteria, test the effect of cleaning with a dry paper towel before disinfectant, and compare various disinfectant compounds and application methods.

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