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Alice Reshamwala, Kathryn McBroom, Yong Il Choi, Linda LaTour, Antoinette Ramos-Embler, Rowena Steele, Virginia Lomudang, Margaret Newman, Colleen Reid, Yanfang Zhao and Bradi B. Granger

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MICROBIAL COLONIZATION OF ELECTROCARDIOGRAPHIC TELEMETRY SYSTEMS BEFORE AND AFTER CLEANING

By Alice Reshamwala, RN, MSN, Kathryn McBroom, RN, BSN, Yong Il Choi, RN, MSN, Linda LaTour, RN, BSN, Antoinette Ramos-Embler, RN, BSN, Rowena Steele, RN, Virginia Lomugdang, RN, Margaret Newman, RN, MSN, Colleen Reid, RN, MSN, Yanfang Zhao, MS, and Bradi B. Granger, RN, PhD

Background Nosocomial infections caused by multidrug-resistant organisms are commonly associated with longer hospital stays up to 12 to 18 days and annual estimated costs of $5.7 billion to $6.8 billion. One common mode of transmission is cross-contamination between patients and providers via surface contaminants on devices such as telemetry systems.

Objectives To determine the effect of a cleaning protocol on colonization of surface contaminants on electrocardiographic telemetry systems in 4 cardiovascular step-down units and to compare colonization in medical vs surgical units.

Methods A prospective, randomized, case-controlled study (the Descriptive Evaluation of Electrocardiographic Telemetry Pathogens [DEET] study) was designed to evaluate microbial colonization on telemetry systems before and after cleaning with sodium hypochlorite wipes. Each randomly selected telemetry system served as its own control. Nurses used a standardized culture technique recommended by personnel in infection control. Colonization before and after cleaning was analyzed by using the McNemar test and frequency tables. A standard cost-comparison analysis was conducted.

Results A total of 30 telemetry systems in medical units and 29 in surgical units were evaluated; 41 telemetry systems (69%) were colonized before the intervention, and 14 (24%) were colonized after it (P < .001). Before cleaning, surface organisms were present in 14 instances (35%) in surgical units and in 27 instances (66%) in medical units (P < .001). The cleaning strategy was cost-effective.

Conclusions The cleaning intervention was effective, and cost-comparison analysis supported implementing a cleaning strategy for reusable leads rather than investing in disposable leads. (American Journal of Critical Care. 2013;22:382-389)
Nosocomial infections, especially those due to gram-negative rods, are associated with hospital stays 12 to 18 days longer than usual hospital stays in which a nosocomial infection does not occur. These infections result in an estimated $5.7 billion to $6.8 billion per year in unnecessary health care costs in the United States. Overall, the annual direct medical cost of nosocomial infections for hospitals is estimated to be $28.4 billion to $33.8 billion. Increases in these costs and concerns for patients’ safety have raised questions about the factors associated with risk for infection, mechanisms of transmission of nosocomial infections, and strategies to better protect patients by preventing nosocomial infection.

A wide variety of risk factors for nosocomial infections have been identified, including patient-linked factors such as severity of illness, prolonged hospitalization, previous antibiotic therapy, and older age with its associated increased susceptibility to infection and equipment-linked factors such as pacemakers, implantable defibrillators, and ventricular assist devices. In addition, providers’ and patients’ behaviors that result in cross-contamination are risk factors for nosocomial infections. Hospital personnel, surfaces, and equipment are common sources of nosocomial infections due to cross-contamination.

Among these risk factors and identified mechanisms for transmission of hospital-acquired infection, reusable electrocardiographic (ECG) leads and telemetry boxes are associated with a particularly high risk, because this health care equipment is transferred between patients, touched by many hospital personnel during a patient’s stay, traditionally not cleaned on a daily basis, and often used by particularly high-risk patients, such as those with open thoracic incisions who are elderly and possibly immunocompromised.

Transmission of high-risk surface contaminants is difficult to combat because of the life span of many common and potentially dangerous microbes ranged from hours to months for common pathogens such as Staphylococcus aureus, Escherichia coli, and Enterococcus subspecies. Of these, the organisms of concern include methicillin-resistant S. aureus, vancomycin-resistant enterococci, certain gram-negative bacilli, and coagulase-negative staphylococci. In particular, staphylococci are a leading cause of major infection after cardiac surgery. Studies have indicated both direct and indirect correlations between environmental contamination with these long-lived organisms and patients’ acquisition of methicillin-resistant and vancomycin-resistant organisms.

Strategies to combat nosocomial infections have been established by multicenter trials, are endorsed by the Centers for Disease Control and Prevention, and are followed by hospital infection control departments. The strategies include shortening the time required to recognize and isolate infected patients, increasing the use of disposable items and equipment used in patient care, and improving the effective choice and disinfection of nondisposables. In 2008, the Centers for Disease Control and Prevention published guidelines for cleaning and sterilization of hospital and patient care items according to the Spaulding classification. In this classification, instruments and equipment to be cleaned and reprocessed are categorized according to the level of risk associated with their intended use. Items and equipment for patient care are classified into 1 of 3 categories (critical, semicritical, and noncritical) on the basis of the degree of risk of infection involved in the use of that particular item. With these classifications, determining what type of disinfectant to use to clean surfaces in patient care areas is easier.

Critical items are those associated with a high risk for infection if the item is contaminated. These items include surgical equipment, cardiac and urinary...
The purpose of our study was to evaluate the effectiveness of a cleaning protocol on telemetry systems in 4 cardiovascular step-down units (2 surgical units and 2 medical units). The study aims were to determine the effect of current cleaning practice on numbers and types of surface contaminants on telemetry systems, to determine if a difference exists in growth of pathogens between medical and surgical units, and to compare the costs for a cleaning strategy with the cost of using disposable ECG electrodes.

Methods

A prospective, randomized case-controlled study (the Descriptive Evaluation of ECG Telemetry Pathogens [DEET] study) with data collected before and after the intervention was used to evaluate colonization by surface contaminants on telemetry systems.

Setting and Sample

A total of 16 telemetry systems were selected randomly from each of the 4 units. Each unit had 31 rooms. The telemetry systems came from occupied and unoccupied rooms. Telemetry systems currently in use in isolation rooms were excluded to decrease the possibility of the study team introducing bacteria. Samples were collected on 2 randomly selected days in June 2010 between 8 AM and noon. Members of the research team were trained by an infection control team in standardized sampling methods to obtain uniform culture samples by using sterile technique.

Procedure

On each clinical unit, each telemetry box and lead wire served as its own control. The box and lead wires were swabbed before the cleaning intervention as the “control” sample and swabbed again after cleaning as the post–cleaning intervention sample. Single sterile culture swabs and individually wrapped 0.52% sodium hypochlorite wipes (Clorox Co) were used. A designated team of staff nurses served catheters, implants, and ultrasound probes used in sterile body cavities. Semicritical items are those that come in contact with mucous membranes or nonintact skin, such as items used in respiratory therapy, anesthesia equipment, and esophageal probes. Noncritical items are those that come in contact with intact skin but not mucous membranes. Examples of noncritical items are blood pressure cuffs, bed rails, linens, patients’ furniture, and floors.26

Cardiac telemetry systems are items that fall between the classifications of semicritical and noncritical for disinfection. Skin integrity and implantable hardware determine the level of risk and susceptibility. As a result, telemetry systems on surgical and medical units may require different cleaning protocols; however, evidence to substantiate this hypothesis is lacking. Although noncritical items are not commonly associated with transmission of infections to patients,27 ECG wires can be a source of colonization for organisms and nosocomial infections. An outbreak of vancomycin-resistant enterococci on a burn unit was traced to a lead wire as a potential source of cross-contamination.27 In addition, Maki and Brookmeyer28 found that one-third of cultured lead wires were reservoirs for antibiotic-resistant organisms. Results of these studies have been cited as the basis and the rationale for using disposable cardiac telemetry lead wires29,30; however, the complete results of the preliminary data from these studies were not published. More research is needed on the role of telemetry systems as a source of nosocomial infections. Although the Spalding classification is helpful for prioritizing cleaning and sterilization of hospital and patient care items, little independent research has been done to determine the most effective strategy for minimizing colonization of microbial flora on ECG electrodes and telemetry boxes.

The purpose of our study was to evaluate the effectiveness of a cleaning protocol on telemetry systems in 4 cardiovascular step-down units (2 surgical units and 2 medical units). The study aims were to determine the effect of current cleaning practice on numbers and types of surface contaminants on telemetry systems, to determine if a difference exists in growth of pathogens between medical and surgical units, and to compare the costs for a cleaning strategy with the cost of using disposable ECG electrodes.

Noncritical patient care items come in contact with intact skin but not mucous membranes.

<table>
<thead>
<tr>
<th>Type of contaminant</th>
<th>Organisms/route of transmission</th>
<th>Length of survival</th>
</tr>
</thead>
<tbody>
<tr>
<td>Multidrug resistant pathogens</td>
<td>Vancomycin-resistant Enterococcus, methicillin-resistant Staphylococcus aureus, Acinetobacter, Klebsiella, Pseudomonas, Shigella</td>
<td>Several months</td>
</tr>
<tr>
<td>Respiratory pathogens</td>
<td>Pertussis, Haemophilus influenzae, Vibrio cholerae</td>
<td>2-6 days</td>
</tr>
<tr>
<td>Respiratory tract viruses</td>
<td>Coxsackie virus, severe acute respiratory syndrome, influenza</td>
<td>2-6 days</td>
</tr>
<tr>
<td>Gastrointestinal viruses</td>
<td>Rotavirus</td>
<td>2 months</td>
</tr>
<tr>
<td>Gastrointestinal bacteria</td>
<td>Clostridium difficile</td>
<td>Several months</td>
</tr>
<tr>
<td>Fungal pathogens</td>
<td>Candida albicans</td>
<td>4 months</td>
</tr>
<tr>
<td>Blood-borne viruses</td>
<td>HIV, hepatitis B virus, hepatitis C virus</td>
<td>&gt;1 week</td>
</tr>
</tbody>
</table>
as the investigators. The team was instructed by personnel from infection control on the uniform technique of swabbing, cleaning, and swabbing again. Hand washing and gloving were maintained before and after swabbing. Specimens from telemetry systems used for cultures were obtained before and after cleaning by swabbing in an S pattern from the front to the back of the equipment and then swabbing the entire length of the lead wires from insertion plug to lead snaps. A 5-minute waiting period after cleaning with the disinfectant wipe was observed per the manufacturer’s recommendation before the telemetry system was swabbed again. Each swab was labeled, refrigerated within 2 hours of collection, and shipped within 48 hours of collection to an independent laboratory for analyses.

**Culture Method**

Swabs were submitted for culturing to detect viable environmental bacteria and fungi. Upon receipt, each swab was diluted in 1 mL of sterile water, and 0.1, 0.01, and 0.001 dilutions of the sample fluid were plated on the appropriate laboratory media for isolating target bacteria or fungi. This method is referenced in the American Industrial Hygiene Association book *Field Guide for the Determination of Biological Contamination in Environmental Samples.*

Cultures for detection of bacteria were incubated at 35°C for 48 hours, whereas cultures for detection of fungi were incubated at 25°C for 5 days. After incubation, microbial colonies were counted and identified by using Gram’s stain, biochemical colonial morphology, and organism-specific identification methods. The assays were performed by an independent laboratory accredited by the American Industrial Hygiene Association in the Environmental Microbiology Laboratory Accreditation Program for environmental bacteriology and mycology.

**Cost Comparison**

The cost of using disposable ECG leads was compared with the cost of using nondisposable leads. Total cost was calculated as follows: total cost = (price of unit [ie, lead] + cost of cleaning) × number of units used (ie, patients treated). In order to calculate the per patient costs for nondisposable leads, the following variables were summed: the annualized depreciation on the cost of single-unit, nondisposable leads; the costs of the cleanser cloths and gloves; and the cost of average nursing time needed to acquire materials and complete the cleaning and drying as recommended by the ECG lead manufacturer. For disposable leads, the following cost variables were summed: the cost of nurses’ time for acquiring disposable leads and attaching them to the telemetry box, “product creep” or the incremental increase in the cost of disposable leads, and the cost of multiple-lead packs used in patients with longer stays (length of stay >5 days requires replacing disposable leads).

**Analysis Method**

The original data collected from the cultures was a continuous count of numbers of colonies by organism type. For each telemetry system, multiple organisms existed. On the basis of the hypothesis that no organisms should be present after cleaning, the variable termed organism growth was dichotomized to a categorical variable of yes or no. The McNemar test was chosen because the data for each telemetry system represented matched pairs of categorical data (yes or no) for the specimens obtained before and after the intervention. In addition, differences in microbial growth in the surgical units compared with medical units were evaluated by using a χ² test.

**Results**

Of the 62 possible patient rooms, 59 rooms had telemetry systems eligible for analysis. A total of 2 sets of samples were lost after the swabbing, and 3 sets of samples were inadvertently not collected. A total of 118 swabs were collected and available for analysis, 59 obtained before cleaning and 59 obtained after cleaning. Types of organisms found on telemetry systems included coagulase-negative staphylococci, bacilli, fermentative gram-negative rods, nonfermentative gram-negative rods, and micrococci (Table 2). Though many organisms were represented in the samples, only 5 telemetry systems had more than a single type of organism that grew concomitantly.

**Overall Growth of Organisms**

The presence of organisms on telemetry systems was significantly decreased after the cleaning intervention (*P* < .001). Before the intervention, organisms were present on 69% (n = 41) of the telemetry systems (Table 3). After the intervention, organisms were present on 24% (n = 14). In 3 instances, the telemetry systems were organism-free at baseline (before cleaning) but had organisms present after the intervention.

**Medical vs Surgical Units**

The types of organisms found before and after cleaning did not differ between medical and surgical...
units. Of the 59 telemetry systems tested, 30 were in medical units, and 29 were in surgical units (Table 3). A total of 41 telemetry systems were positive for growth of organisms before cleaning: 27 (66%) in medical units and 14 (34%) in surgical units. After the intervention, the medical units had growth of organisms on 10 telemetry systems (33%), and the surgical units had growth on 4 (14%). The difference between the 2 units was not significant \((P = .58)\). However, growth of organisms before cleaning differed between surgical and medical units.

In the 1 surgical unit with a much lower rate of microbial growth (19%) than the rates of growth in the other units (85%-93%), a practice difference related to storage of unused telemetry boxes was identified as the likely cause of the difference.

### Discussion

Our findings indicate that a standard cleaning protocol can significantly reduce the presence of surface pathogens on ECG telemetry systems. These findings suggest that although telemetry lead wires are a source of potentially harmful surface contaminants, and an increased concern for patient safety, a standard cleaning strategy can reduce microbial growth to safe and acceptable levels. A review of the literature revealed only 2 studies\(^{32,33}\) in which telemetry lead wires were examined as a source of surface contamination. In the most recent study, Albert et al\(^{32}\) examined 320 telemetry systems in 4 hospitals and various settings of care and found harmful pathogens on the surfaces of the systems. The systems in the emergency department and telemetry units had more organisms than did the systems in the operating rooms or critical care areas.

This increased prevalence of organisms reported by Albert et al\(^{32}\) was a foundational starting point for our study. Our findings add to the existing literature by indicating the benefits of a standard cleaning protocol in reducing the presence of harmful pathogens. The cleaning strategy effectively removed organisms present on telemetry systems (Table 3).

The prevalence and type of organisms present on the telemetry systems in our study was similar in medical and surgical units. Interestingly, the prevalence of organisms in 1 surgical unit was significantly lower than the prevalence in the other 3 units (see Figure). In the unit with the lowest prevalence, 3 telemetry systems had organisms present before the intervention, and 2 systems had organisms present after the intervention. The reason for the difference was further investigated and was subsequently attributed to a different storage policy for the telemetry boxes: the boxes were cleaned and then stored in a central location at the nurses’ station rather than in patients’ rooms. In addition, the boxes were cleaned a second time before use with a new patient. In all the other units, however, telemetry boxes were stored in the individual patient rooms between use. Staff conducted brief observations of practice patterns and concluded that storage in the central may have contributed to greater visibility, increased public

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**Table 2**

<table>
<thead>
<tr>
<th>Organisms</th>
<th>Total No. of telemetry systems</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coagulase-negative staphylococci</td>
<td>36</td>
</tr>
<tr>
<td>Bacilli</td>
<td>1</td>
</tr>
<tr>
<td>Fermentative gram-negative rod</td>
<td>2</td>
</tr>
<tr>
<td>Nonfermentative gram-negative rod</td>
<td>1</td>
</tr>
<tr>
<td>Micrococci</td>
<td>1</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>41</strong></td>
</tr>
</tbody>
</table>

---

**Table 3**

<table>
<thead>
<tr>
<th>Type of unit</th>
<th>Before intervention</th>
<th>After intervention</th>
<th>(P)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Yes</td>
<td>No</td>
<td>Total</td>
</tr>
<tr>
<td>Medical</td>
<td>27 (90)</td>
<td>3 (10)</td>
<td>30 (100)</td>
</tr>
<tr>
<td>Surgical</td>
<td>14 (48)</td>
<td>15 (52)</td>
<td>29 (100)</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>41 (69)</td>
<td>18 (31)</td>
<td>59 (100)</td>
</tr>
</tbody>
</table>

---

**Figure** Microbial growth on telemetry systems by unit before and after cleaning intervention.
scrutiny, and, possibly, a more thorough cleaning than the cleaning used in the other 3 units.

In addition to the overall low prevalence of microbial growth in this surgical unit, 3 of the telemetry boxes were organism-free before cleaning but had organisms after cleaning. One possible explanation is that a labeling error occurred at the time of data collection.

Recently, attempts to reduce the risk for nosocomial infection by reducing surface contaminants have focused on the potential advantage of using disposable ECG telemetry leads. Because of the significant decrease in surface contaminants achieved by using a short cleaning intervention, and the similarities in actual rates of nosocomial infection in the 4 cardiac units, we compared the cost of cleaning with the cost of using disposable leads (Table 4).

Table 4
Cost comparison of disposable vs nondisposable electrocardiography leads

<table>
<thead>
<tr>
<th>Unit name (31 monitors per unit)</th>
<th>Total cost of disposable leadsa</th>
<th>Projected No. of patients per year</th>
<th>Fixed cost of nondisposable leads @ $52.50 per lead,b $</th>
<th>Annual cost of cleaning nondisposable leads,c $</th>
</tr>
</thead>
<tbody>
<tr>
<td>3100</td>
<td>$29,557.30</td>
<td>2374.08</td>
<td>$1627.50</td>
<td>$854.67</td>
</tr>
<tr>
<td>3300</td>
<td>$32,310.24</td>
<td>2595.20</td>
<td>$1627.50</td>
<td>$934.27</td>
</tr>
<tr>
<td>7100</td>
<td>$44,198.50</td>
<td>3550.08</td>
<td>$1627.50</td>
<td>$1278.03</td>
</tr>
<tr>
<td>7300</td>
<td>$30,613.93</td>
<td>2458.95</td>
<td>$1627.50</td>
<td>$885.22</td>
</tr>
<tr>
<td>Total</td>
<td>$136,679.97</td>
<td>10,978.31</td>
<td>$6510.00</td>
<td>$3952.19</td>
</tr>
</tbody>
</table>

a Total cost of disposable leads = price per patient x projected number of patients per year x price per lead set x volume of disposable lead sets where volume of disposable lead sets = No. of lead sets per patient x No. of lead sets per monitor x No. of monitors per unit. (Disposable leads must be replaced every 7 days, so some patients require more than 1 set of disposable leads.)
b Fixed cost of nondisposable leads = price per lead set x No. of monitors per unit. The fixed cost of nondisposable leads is incurred in year 1 only. Thereafter the only cost is cleaning, as nondisposable leads do not have to be replaced every 7 days.
c The variable cost for cleaning nondisposable leads per unit = (cost of cleaning leads + nursing care hours) x (projected No. of patients), which is [(1 wipe @ $12.43/60 wipes) + (15 seconds @ $35/hour)] x projected No. of patients, which is ($0.21 per patient + $0.15 per patient) x projected No. of patients.

A marked decrease in length of stay, or handling of the lead that results in damage cause the cost of disposable ECG leads to increase dramatically.

In contrast, the cost of cleaning ECG leads between patients is minimal and includes the costs of a nurse’s time, a pair of gloves, and a simple cleaning product. Our cleaning protocol resulted in a significant reduction ($P < .001) in the presence of organisms on the ECG telemetry systems and lead wires at a relatively low total cost ($0.21/patient).

The cost of nosocomial infection is primarily associated with prolonged length of hospital stay, during which patients incur preventable bed-days and require additional diagnostic and therapeutic interventions. Although the scope of our study was not large enough to show an effect on rates of infection, the use of a standard cleaning protocol may result in additional savings through lower rates of hospital-associated infections, reduced length of stay, and decreased cost of inpatient care. Cleaning nondisposable ECG leads presents an opportunity for measurable cost savings at 2 levels: the daily cost of care delivery and the larger costs of a reduction in nosocomial infections.

The estimated average costs per patient associated with 1 episode of nosocomial infection2–3 are $20,549 to $25,903. Costs associated with infection at a surgical site range from $11,874 to $34,670 per patient, and catheter-associated bloodstream infections cost $7,288 to $29,156 per patient.2–4 Use of disposable ECG leads might decrease risk of transmission and cross-contamination and thus result in cost savings. Manufacturers of ECG leads suggest that the products may improve hospital system safety profiles by enhancing infection prevention strategies in patient care areas.3,4 However, many studies on the advantages...
Cleaning nondisposable leads is more cost-effective than purchasing disposable leads.

Disposable ECG lead sets offer a strategy for significantly reducing patients’ exposure to surface contaminants at a minimal cost. Costs associated with actual cases of nosocomial infection are far greater than the costs associated with using disposable leads. However, careful cleaning of nondisposable leads may be equally safe and even more cost-effective, as our results suggest.

On the basis of our findings, we make the following 3 recommendations: adopt a practice of cleaning telemetry systems with sodium hypochlorite wipes between patients and at intervals of 3 days for patients with a prolonged stay; establish a hospital-wide protocol for cleaning telemetry systems and other semicritical items, such as stethoscopes and bedside temperature monitors; and adopt a centralized storage area for telemetry systems, as done by the surgical unit in our study that had significantly fewer organisms present on the telemetry systems before cleaning than the other units did. The importance of implementing a process standard or practice policy to implement a proven telemetry cleaning strategy is also a key clinical implication of our results.

Conclusion
Our results indicate that the proper use of a bleach-based cleaning product can significantly reduce microbial growth on ECG telemetry systems. The findings support the effectiveness of a standardized protocol for cleaning telemetry systems in cardiovascular patient care areas and suggest that implementation of such a protocol is equally effective in both medical and surgical units. The results of a cost-comparison analysis did not support clinical use of disposable ECG leads for patient safety.

REFERENCES

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