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ORIGINAL ARTICLE

Evaluating Use of Neutral Electrolyzed Water for Cleaning Near-Patient Surfaces

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OBJECTIVE. This study aimed to monitor the microbiological effect of cleaning near-patient sites over a 48-hour period with a novel disinfectant, electrolyzed water.

SETTING. One ward dedicated to acute care of the elderly population in a district general hospital in Scotland.

METHODS. Lockers, left and right cotsides, and overbed tables in 30 bed spaces were screened for aerobic colony count (ACC), methicillin-susceptible *Staphylococcus aureus* (MSSA), and methicillin-resistant *S. aureus* (MRSA) before cleaning with electrolyzed water. Sites were rescreened at varying intervals from 1 to 48 hours after cleaning. Microbial growth was quantified as colony-forming units (CFUs) per square centimeter and presence or absence of MSSA and MRSA at each site. The study was repeated 3 times at monthly intervals.

RESULTS. There was an early and significant reduction in average ACC (360 sampled sites) from a before-cleaning level of 4.3 to 1.65 CFU/cm^2 at 1 hour after disinfectant cleaning ($P < .0001$). Average counts then increased to 3.53 CFU/cm^2 at 24 hours and 3.68 CFU/cm^2 at 48 hours. Total MSSA/MRSA (34 isolates) decreased by 71% at 4 hours after cleaning but then increased to 155% (53 isolates) of precleaning levels at 24 hours.

CONCLUSIONS. Cleaning with electrolyzed water reduced ACC and staphylococci on surfaces beside patients. ACC remained below precleaning levels at 48 hours, but MSSA/MRSA counts exceeded original levels at 24 hours after cleaning. Although disinfectant cleaning quickly reduces bioburden, additional investigation is required to clarify the reasons for rebound contamination of pathogens at near-patient sites.

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Hospital pathogens, such as methicillin-resistant *Staphylococcus aureus* (MRSA), can persist in the healthcare environment for months.[1] The most important reservoirs are hand-touch sites beside the patient, especially bedside locker, overbed table, and bed frame.[2-5] High levels of microbial flora on these surfaces are associated with increased risk of finding methicillin-susceptible *S. aureus* (MSSA) and MRSA.[3]

Current United Kingdom cleaning regimens specify detergent cleaning for near-patient furniture and beds, unless there are specific recommendations for disinfectant use.[6,7] The usual choice is sodium hypochlorite, which is toxic and has to be freshly prepared.[7] Neutral electrolyzed water is based on a stable form of hypochlorous acid (pH, 6–8) produced by passing an electric current through water with added salt.[8] This product might be useful for hospital cleaning, given its microbicidal effects, low toxicity, long shelf life, and promising performance in care homes.[9,10]

The aim of this study was to evaluate the impact of cleaning near-patient sites with electrolyzed water on an acute hospital ward. Surfaces were screened before cleaning and then at varying intervals afterward using standardized methods. We measured the immediate effect of disinfection and rate of recontamination over time. We also aimed to compare the effect of electrolyzed water against data from a previous study in which identical sites on a similar ward were cleaned using detergent only.[11]

SETTING

One ward devoted to acute care of the elderly population in a 450-bed National Health Service (NHS) hospital was chosen as the study ward. The 30-bed ward is maintained at 100% bed occupancy, with patients resident in 6 ensuite single rooms and 4 bays each containing 6 beds. Although patients of either sex can reside in single rooms, 3 of the 4 bays accommodated female patients.

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TABLE 1. Effect of 3 Electrolyzed Water Cleanings on Total Aerobic Colony Count (ACC)/cm^2 and Methicillin-Susceptible *Staphylococcus aureus* (MSSA)/Methicillin-Resistant *S. aureus* (MRSA) at High-Risk Sites on a 30-Bed Acute Care Ward over a 48-Hour Period

	Hours after cleaning							
Variable	0[a]	1	2	4	8	12	24	48
Total ACC/cm^2								
By site type								
1	131	24	27	37	75	86	163	118
2	106	38	27	36	68	67	72	100
3	150	110	88	92	90	103	136	125
4	128	26	58	49	78	61	52	99
Average per site type	129	49	50	53	78	79	106	110
Average per site								
All rooms	4.3	1.65	1.66	1.75	2.59	2.63	3.53	3.68
Side rooms[b]	4.37	1.71	1.37	1.37	1.87	3.21	2.87	4.21
No. of MSSA and MRSA isolates								
By site type								
1	12	2	0	2	3	9	19	9
2	5	4	1	1	2	2	6	5
3	12	10	8	6	6	15	15	13
4	5	2	5	1	3	5	13	9
Overall								
All rooms	34	18	14	10	14	31	53	36
Side rooms[b]	12	2	5	3	4	4	13	8
Average per site type	8.50	4.50	3.50	2.50	3.50	7.75	13.25	8.00

NOTE. Hygiene standard was <5 colony-forming units/cm^2. Site 1, bedside locker; site 2, right cotside; site 3, overbed table; site 4, left cotside.

[a] Before cleaning.

[b] Data are for 6 single-bed side rooms.

METHODS

Four sites (bedside locker; left cotside; overbed table; right cotside) in 30 bed spaces were screened using standardized microbiological methods for assessing surface cleanliness.[12,13] Each site was then sprayed with 1.5 mL electrolyzed water (Salvesan; Aqualution), wiped clean with detergent wipes 10–15 seconds later (Tuffie detergent wipes; Vernacare), and allowed to dry naturally. Four wipes were allocated for each bed space. The study was repeated 3 times (phases 1–3) over a 4-month period to supply all data in triplicate.[11] Each phase was performed independently, and the same screening protocol was performed before and after cleaning. Beds and lockers are normally cleaned every day using detergent. These sites had been cleaned approximately 22 hours before the study began, with overbed tables cleaned after supper the previous evening (ie, 12 hours before the initial screening).

Two senior physicians performed the cleaning for each phase after training and assessment using microbiological methods. Study personnel wore freshly laundered overalls and washed hands with soap and water before and during screening and cleaning. Sites were rescreened at 1 hour, 2 hours, 4 hours, 8 hours, 12 hours, 24 hours, and 48 hours after cleaning with disinfectant. Precleaning screening began at 7 AM and was immediately followed by cleaning so that all sites could then be screened 1 hour later. Screening and cleaning adhered to a planned systematic program so that each site was sampled at the same time intervals after cleaning. The screening 24 hours after cleaning was initiated at 8 AM on the following day, and a final screening was performed at 8 AM 2 days later (48 hours after cleaning).

Normal ward care for patients continued throughout the study and included routine cleaning of floors and toilet facilities, which was performed by domestic staff. No additional cleaning of study sites, which were usually cleaned by nurses, took place until after the 48-hour screening, other than attention to spillages. The protocol was discussed with domestic managers and senior nurses to coordinate the study with routine ward practices. Ethical exemption was obtained from NHS Lanarkshire Research and Development.

Microbiology

Screening was performed using dipslides (Hygiena) coated with nutrient and staphylococcal selective (Baird Parker) agars.[3,11-13] After sampling, dipslides were incubated for 48–72 hours according to laboratory protocol. Slide placement at each site was performed systematically in accordance with a predetermined template so that slides did not sample areas previously screened.

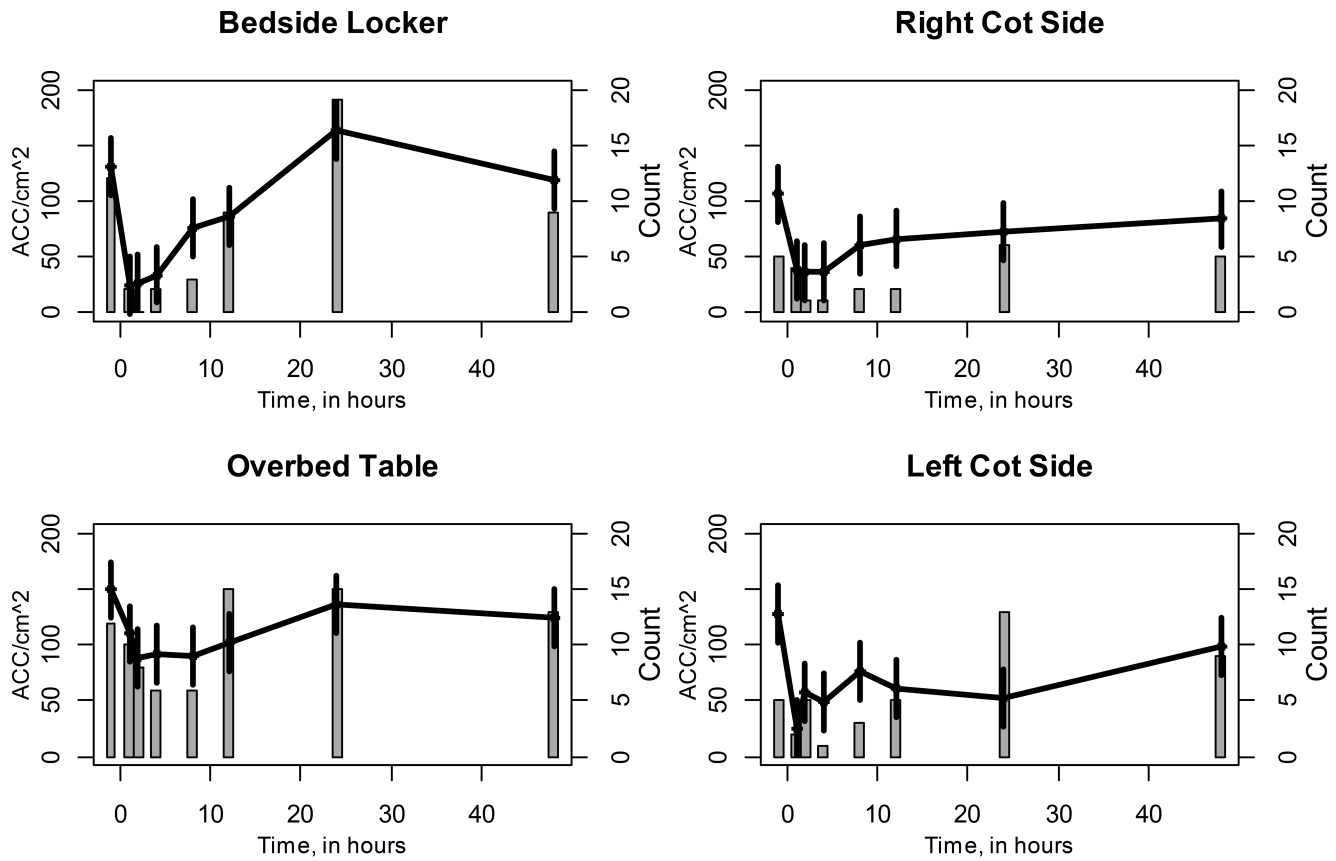

FIGURE 1. Aerobic colony count (ACC)/cm^2 and total number of methicillin-susceptible *Staphylococcus aureus* (MSSA) and methicillin-resistant *S. aureus* (MRSA) isolates for all sampled sites over a 48-hour period before and after cleaning with electrolyzed water (time = 0). This figure shows the relationship between trends in ACC and MSSA/MRSA isolates for each site averaged over 3 study phases. The black line represents ACC (left axis), including the confidence interval for the mean based upon the linear regression model; the gray bars represent numbers of MSSA/MRSA isolates (right axis). The similarities in the trends are greatest for the bedside locker and overbed table.

Growth on nutrient agar supplied total aerobic colony count (ACC) per cm^2, classified as no growth; scanty growth, defined as less than 2.5 CFU/cm^2; light growth, defined as 2.5–12 CFU/cm^2; moderate growth, defined as 12–40 CFU/cm^2; or heavy growth, defined as greater than 40 CFU/cm^2.[3,11,13] Selective agar highlighted coagulase-positive staphylococci, which were subcultured onto blood agar and characterized. Hygiene standards have been proposed whereby ACC greater than 5 CFU/cm^2 and/or presence of MSSA/MRSA at a hand-touch site indicates increased infection risk for patients.[12-14]

The methods duplicate those used for a previous study, performed by the authors 6 months earlier.[11] This study took place in an identical ward situated on the floor below in the same building. Both wards belong to the same unit and have similar case-mix, patient turnover, bed occupancy rates, and staffing. They have the same layout, design, and cleaning protocols and are managed by a single clinical team. The same 4 sites were screened before cleaning with detergent wipes and then rescreened at the same intervals after cleaning. Dipslides were processed as already described.[11]

Statistical Analyses

All data were subjected to statistical analyses. Each of the 4 sites around 30 beds at 0, 1, 2, 4, 8, 12, 24, and 48 hours after cleaning supplied an ACC categorized as indicated, along with numbers of MSSA/MRSA isolates. Each study phase provided a series of results for 30 × 4 sites, ultimately giving data for 360 sites. We compared total mean ACC against time and site to ascertain recontamination rate after cleaning. Total MSSA and MRSA isolates were also calculated and plotted over time. Data were analyzed for single rooms versus multiple patient bays.

This was an observational study, and analysis of variance methods were used to assess the importance of time from cleaning, site, and phase on total ACC for 4 sites around 30 beds. The main investigation centered on modeling ACC trends over time using a linear regression model. We assumed

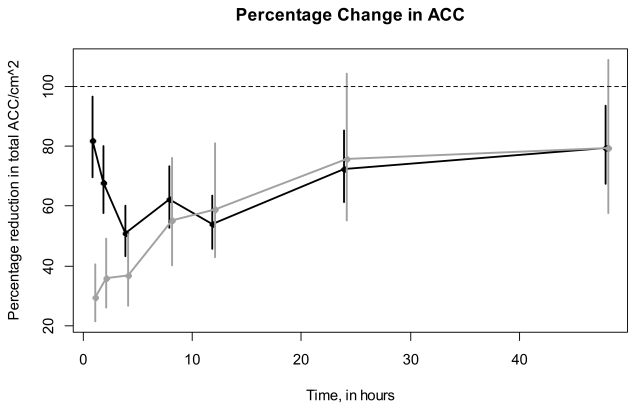

FIGURE 2. Effect of detergent and disinfectant-based cleaning on total aerobic colony count (ACC)/cm^2) at 4 near-patient sites on a 30-bed ward over 48 hours. These are the estimated percentages relative to the baseline ACC/cm^2 derived from a statistical model of the log ratio of ACC at time = 1, 2, 4, 8, 12, and 24 hours relative to baseline. The model accounts for differences between the 3 phases as well as time and averages over the trends in the 4 sites. The detergent is plotted in black, and electrolyzed water is plotted in gray. The vertical lines are the 95% confidence intervals for the percentage ACC relative to baseline.

normal distribution for total ACC, and the assumptions of the model, including the absence of serial correlation, were validated through residual plots. Two-way interactions were tested using F tests at the prespecified 1% significance level, because these were of secondary importance, whereas the main effects were tested at the 5% level. Poisson regression was employed for the analysis of numbers of MSSA/MRSA isolates detected, with a χ^2 deviance test used.

RESULTS

Cleaning with electrolyzed water resulted in an immediate reduction in ACC at each site for all phases (Table 1). Figure 1 shows the mean ACC (CFU/cm^2) and number of MSSA/MRSA isolates at all sites and screening times. Overall ACC decreased from 4.3 CFU/cm^2 before cleaning to 1.65 CFU/cm^2 at 1 hour after cleaning ($P < .0001$). This level gradually increased to 3.68 CFU/cm^2 at 48 hours after cleaning, which was less than that obtained before cleaning.

The reduction in average ACC occurred for all 4 sites after cleaning (Table 1; Figure 1). The pattern is similar for each site, with ACC significantly lower than baseline for 1–12 hours. There is a return to baseline levels at 24 hours for 2 sites (locker and right cotside) and for all sites by 48 hours. Microbial recovery was higher from overbed tables than from lockers and cotsides. The patterns of recovery over time are different for each site, and this is primarily due to the different pattern for the bedside locker compared with the other 3 sites ($P = .0028$, by interaction test).

The reduction profile of viable MSSA/MRSA differed from ACC, because the highest numbers were found at 24 hours, not 48 hours, after cleaning (Table 1; Figure 1). There are significant differences between phases ($P < .0001$), sites ($P < .0001$), and times ($P < .0001$).The total number of isolates for all 3 phases decreased by 71%, from 34 isolates (before cleaning) to 10 isolates (29%) at 4 hours after cleaning. The numbers then increased to reach the highest level of 53 isolates (155%) at 24 hours, with 36 isolates (106%) recovered at 48 hours. Relative to the locker (56 isolates), there were fewer MSSA/MRSA isolates recovered from the cotsides (27 and 42 isolates), with the highest number overall from overbed tables (85 isolates).

Because of the relatively large numbers of staphylococci, MSSA and MRSA were examined independently (data not shown). For MRSA, there were no differences between phases ($P = .683$) or over time ($P = .289$), but MRSA was recovered from the overbed table ($P = .006$) more frequently than from the other sites. MSSA data were similar to total MSSA/MRSA data, because the number of MRSA isolates recovered was relatively small compared with the number of MSSA isolates. There were no known patient clusters of either MSSA or MRSA in the ward during the study.

Sites in 6 single rooms (20% of total beds) yielded proportionately similar total ACC compared with multibed room sites before and 1 hour after cleaning (Table 1). Lower numbers of ACC were recovered from single rooms compared with multibed rooms at 2–8 hours after cleaning, but the number of ACC recovered from single rooms compared with multibed rooms reached proportionately higher levels at 48 hours. These differences are not statistically significant over time ($P = .28$), nor are there any differences in average ACC between single rooms and multibed rooms (mean difference, 0.07 ACC/cm^2 per bed [95% confidence interval, −0.39 to 0.53]; $P = .76$). Single-room sites yielded proportionately more staphylococci before cleaning when compared with multibed rooms ($P < .0001$), probably because of isolated patients with MRSA infection during 2 phases. The apparent rebound in total MSSA/MRSA at 24 hours occurred in single rooms as well as multibed rooms (Table 1).

In the earlier study using detergent, the average ACC decreased from a precleaning level of 6.72 CFU/cm^2 to 3.46 CFU/cm^2 at 4 hours after cleaning ($P < .0001$).[11] Although before-cleaning ACCs are lower in this study, the effects on microbial load and MSSA/MRSA after both types of cleaning can be compared. Figure 2 shows percentage reduction of ACC after each type of cleaning over 48 hours. ACC decreased more rapidly after exposure to disinfectant and achieved a relatively lower level (49% reduction of ACC for detergent vs 63% reduction for disinfectant at 4 hours, although the confidence intervals overlap). There is little difference for levels of accumulated ACC at 8, 12, 24, and 48 hours for both types of cleaning.[11]

Figure 3 shows percentage reduction of number of MSSA/MRSA isolates after detergent and disinfectant cleaning. Total staphylococci decreased to a minimum level at 4 hours in both studies, but although numbers returned to precleaning

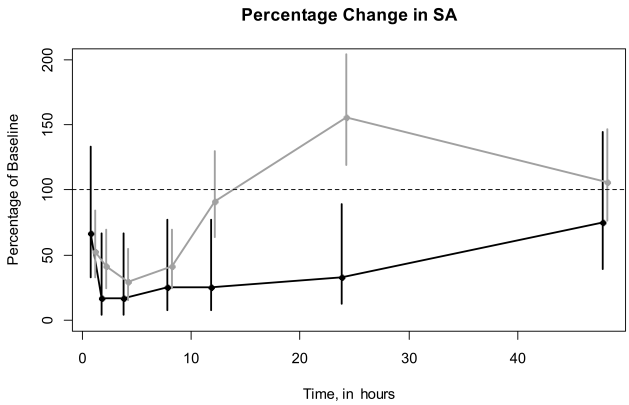

FIGURE 3. Effect of detergent- and disinfectant-based cleaning on total methicillin-susceptible *Staphylococcus aureus* (MSSA) and methicillin-resistant *S. aureus* (MRSA) recovered from 4 near-patient sites on a 30-bed ward over 48 hours. These are the estimated percentages relative to the baseline staphylococcal (SA) count derived from a Poisson regression model of isolate numbers of MSSA/MRSA at time = 1, 2, 4, 8, 12, and 24 hours aggregated over site and phase, including an offset for the log MSSA/MRSA isolates and baseline. Detergent effect is plotted in black and electrolyzed water in gray. The vertical lines are the 95% confidence intervals for the percentage count relative to baseline. Both types of cleaning rapidly reduced the overall staphylococcal burden, but recontamination occurred more rapidly after disinfectant exposure. The sites monitored were bedside locker, right and left cotsides, and overbed table, and each type of cleaning was repeated 3 times.

levels at 48 hours after detergent, the number of isolates retrieved at 24 hours after disinfectant greatly superseded original levels (although this was not the case at 48 hours).

DISCUSSION

This study sought to demonstrate the effect of cleaning with a novel disinfectant, electrolyzed water, on bioburden at near-patient sites on an acute ward. We also wanted to establish how quickly microbial levels accumulated after cleaning, having investigated this earlier.[11] Disinfectant cleaning rapidly reduced ACC on screened surfaces, with levels at 48 hours the same or less than those obtained at the precleaning stage. In contrast, the number of MSSA/MRSA isolates reached a minimum level at 4 hours but then demonstrated an unexpected surge at 24 hours.

This study has some limitations. Despite allowing intervals of at least 1 month between phases, there may have been a Hawthorne effect by staff between and during study phases. Staff invariably respond to any measure of cleaning activity by improving performance.[6] Second, we did not know how well study sites were cleaned the day before the cleaning initiative, although precleaning ACC levels were similar for all sites and phases (Table 1). Comparing this study with that performed previously, it is possible that spray delivery of electrolyzed water might have encouraged dispersal of bioburden, aside from any microbiocidal impact. Certainly, overall bioburden was lower throughout this study, which was initially attributed to seasonal differences. Finally, there are no data on intensity of activity on the ward during each phase, including contributions from air, ambient temperature, and humidity toward recontamination of screened sites. The ward was fully occupied throughout the study.

Another study examined bioburden at near-patient sites before and after cleaning.[15] Screening was performed at half-hour intervals for 7 hours after disinfectant cleaning, the bedrails beside 6 critical care beds were screened 6 times, and microbial levels were quantified as CFU/100 cm^2 (we used CFU/cm^2). Mean bacterial concentration on bedrails (n = 36) before cleaning was 4,756 CFU/100 cm^2, whereas the mean ACC on cotsides, locker, and table (n = 360) in this study was 4.3 CFU/cm^2. The log difference in microbial levels may be due to different sampling methods and their relative sensitivities.[16]

The pattern of viable staphylococci recovered over 48 hours provided the most striking difference between detergent and disinfectant cleaning (Figure 3). Preclean MSSA/MRSA numbers were dissimilar between the studies, reflecting variable presence of staphylococcal carriers, but standardizing the data reveals an unexpected surge in staphylococcal recovery 24 hours after disinfectant exposure. An earlier study using hydrogen peroxide disinfection also reported rapid reappearance of MRSA within 24 hours.[17] There is no obvious explanation for the rebound contamination, unless exposure to electrolyzed water encourages hard surface biofilm to release viable planktonic staphylococci. Recent work has confirmed survival of MRSA within biofilm on dry hospital surfaces.[18]

The overall effect of neutral electrolyzed water on surface bioburden at 24–48 hours was similar to that obtained after detergent cleaning (Figure 2). Detergent alone may be sufficient for routine ward cleaning. Electrolyzed water could be useful for cleaning between patients in outpatient settings, however, because the speed and effect of disinfection would alleviate contamination concerns in busy clinics. Physical removal of bioburden appears to be just as effective as disinfectants for controlling microbial soil.[19-23] This is partially, but not fully, explained by the fact that the microbiocidal activity of a disinfectant is inversely proportional to the degree of organic soil on a surface.[24] More work is required to clarify this, because aside from cost issues, detergents are less toxic and are unlikely to promote acquisition of resistance genes among environmental bacteria.[24]

In conclusion, cleaning with electrolyzed water reduced microbial load at near-patient sites on an acute care ward. The reduction profile suggests that these sites should be cleaned once per day, because the time period before recontamination was approximately 24 hours. Overbed tables require greater frequency of cleaning. Additional work is required to examine the relationship between disinfectant exposure and rebound contamination of MSSA/MRSA at 24 hours compared with detergent-based cleaning.

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