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Methicillin-Resistant Staphylococcus aureus (MRSA) Burden in Nursing Homes is Associated with Environmental Contamination of Common Areas

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Abstract

Background—Variation in MRSA prevalence across nursing homes is poorly understood. Differences in environmental cleaning may be one source of variable MRSA burden.

Design—Prospective study of environmental contamination and cleaning quality.

Setting/Participants—10 California nursing homes.

Measurements—We categorized nursing homes into two groups based upon high and low differences in MRSA point prevalence and admission prevalence (delta prevalence) from nares screenings of nursing home residents. We evaluated environmental cleaning and infection control practices by (a) culturing common area objects for MRSA, (b) assessing removal of intentionally-applied marks visible only under ultraviolet light (c) administering surveys on infection control and cleaning.

Results—Overall, 16% (78/500) of objects were MRSA-positive, and 22% (129/577) of UV-visible marks were removed. A higher proportion of MRSA-positive objects was found in the high vs. low nursing home groups (19% vs. 10%, p=0.005). Infection control and cleaning policies varied, including the frequency of common room cleaning (mean 2.5 times daily, range 1–3) and time spent cleaning per room (mean 18 min, range 7–45). In multivariate models, MRSA-positive objects were associated with high delta prevalence nursing homes (OR=2.8, p=0.005), facilities

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Author Contributions

Courtney Murphy: study design, data collection and analysis, manuscript preparation. Samantha Eells: study design, environmental sample processing. Victor Quan, Diane Kim: study design. Ellena Peterson: study design, pilot study sample processing. Loren Miller: study design, environmental sample processing. Susan Huang: study design, data analysis, manuscript preparation.

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Conflict of Interest

All authors report no conflict of interest.

spending less time cleaning each room (OR = 2.9, p<0.001) and facilities where common rooms were cleaned less frequently (OR =1.5, p=0.01).

Conclusions—We found substantial variation in MRSA environmental contamination, infection control practices, and cleaning quality. MRSA environmental contamination was associated with larger differences between MRSA point and admission prevalence, less frequent common room cleaning, and less time spent cleaning per room. This suggests that modifying cleaning practices may reduce both MRSA environmental contamination and burden among nursing homes.

Keywords

Methicillin-resistant Staphylococcus aureus (MRSA); environmental contamination; cleaning quality; infection control; long term care facility

INTRODUCTION

Nursing homes can have a high prevalence of MRSA colonization (5–50%),[1–6] often surpassing that found in hospitals (6–12%)[7–9] and intensive care units (10–16%)[10–12]. We previously reported that MRSA point prevalence substantially exceeded MRSA admission prevalence in several nursing homes, suggesting that transmission may be occurring.[13] These differences in MRSA point and admission prevalence were not explained by higher length of stay among MRSA-positive residents. Moreover, we found that the difference in prevalences varied greatly across nursing homes, suggesting MRSA may be better contained in some nursing homes than in others regardless of how much MRSA is imported into the facility. This variability across nursing homes suggests that specific practices and policies may affect MRSA burden.

Sources of MRSA are not well studied in nursing homes. A previous study found that infection control policies varied widely among nursing homes.[14] It is not practical for nursing homes to follow the same guidelines for infection control as hospitals, due to the need to foster a home-like environment for residents.[15] Nevertheless, this latitude has led to non-standardized infection control policies in nursing homes, including when to discontinue barrier precautions for residents with MRSA infection or restrict these residents from common dining and activity areas until their infection clears. Such differences in infection control policy or practice may explain differences in MRSA burden in nursing homes.

Differences in MRSA burden in nursing homes may also relate to variable levels of environmental contamination. Environmental contamination has been linked to MRSA transmission in hospitals[16–20] and may be similarly influential in nursing homes. In fact, environmental contamination may play a larger role in MRSA prevalence in nursing homes since, in contrast to hospitalized patients who often do not leave their bed or interact with other patients, nursing home residents are encouraged to socialize in shared dining and activity areas. Extensive exposure in common areas may explain the recent finding that roommate interaction was not a major source of MRSA transmission.[21] Cleaning quality may be especially important in nursing homes due to frequent resident interaction. A UV-light marker (only visible under ultraviolet light) designed to be easily removed by cleaning (moisture and light to moderate pressure) has been shown to reflect cleaning quality and levels of MRSA contamination in hospitals.[16,22–24] We previously showed that removal of this marker was associated with reduced environmental MRSA contamination following a cleaning intervention in ICUs, suggesting that improved cleaning may reduce MRSA burden.[16]

We evaluated nursing homes' current infection control and cleaning policies and assessed whether MRSA environmental contamination and quality of cleaning in common areas

based upon culture and use of a black light marker were associated with differences in MRSA prevalence in this setting.

METHODS

We categorized 10 nursing homes from Orange County, California, into two groups based upon previously obtained MRSA point prevalence and admission prevalence data.[13] These nursing homes deliver care to a mixture of short- and long-term stay residents. At each nursing home, we collected bilateral nares swabs from 100 residents at a single visit (percent positive residents = MRSA point prevalence) and 100 consecutive residents upon admission (percent positive residents = MRSA admission prevalence). For one nursing home with infrequent turnover, we swabbed 50 residents upon admission. We categorized nursing homes into two groups based upon high and low differences in MRSA point prevalence and admission prevalence (delta prevalence), where high MRSA delta prevalence was defined as an absolute difference of 10 or greater.

Environmental Sampling for MRSA

At each nursing home, we cultured the same 10 objects in common areas during 5 separate visits (10 objects per visit, 50 samples total). For both swabbing and mark placement, we used a list of 10 high-touch items which was developed a priori in consultation with nursing home staff; these objects were: nurse station counter or cart, rehabilitation equipment, two tables (one each from dining and activity rooms), two chairs (one each from dining and activity rooms), and four hallway objects (one drinking fountain, one payphone, one handrail and one doorknob). Objects were swabbed qualitatively using pre-hydrated sponges (Spongestick with neutralizing buffer, Biotrace 3M) over an area less than 100 cm^2. Swabs were processed within 18 hours after collection at Los Angeles Biomedical Research Institute and were incubated in tryptic soy broth with 7% NaCl for 18–24 hours. Swabs were tested for MRSA using selective media plates (CHROMagar, BD Diagnostics, CITY) and confirmed as S. aureus using Staphaurex (Remel, CITY).

Evaluation of Routine Cleaning

At each nursing home, we also placed UV-visible marks[18] on 10 objects during 6 separate visits (10 objects per visit, 60 samples total). Cleaning marks were evaluated for removal the next day, using a UV penlight. We marked and swabbed the same list of objects in each facility. For each object swabbed or marked, we recorded the date, object type, and room where the object was located.

Survey on Infection Control and Environmental Cleaning Policies

To understand infection control and environmental cleaning policies, we conducted a survey at each participating nursing home. Questions on infection control policies were administered to the director of infection control at each facility by a member of the research staff and included: criteria for initiating and discontinuing contact precautions for patients with MRSA, whether MRSA positive patients were restricted from common areas, whether screening was conducted for MRSA carriers, and the proportion of management time devoted to infection control and prevention. Questions on environmental cleaning practices were administered to the director of environmental cleaning services by a member of the research staff and included: how often common areas were cleaned per day, how many rooms were assigned to each cleaning staff member, how much time was spent cleaning a room, which products were used for cleaning, and whether contact precaution rooms were cleaned last. The entire survey contained 74 questions (33 on infection control and 41 on environmental cleaning) and required approximately one hour to complete.

Bivariate and Multivariate Analyses of Environmental MRSA and Cleaning Marks

We conducted bivariate and multivariate analyses. We used chi-square tests to evaluate the association between percent culture-positive objects and a variety of variables, including object type, whether the object was flat (tables, nurse station counters or carts, rehabilitation room mats), the object's room location, facility infection control practices, environmental cleaning practices, and the nursing home's MRSA admission prevalence and MRSA delta prevalence group. We separately used chi-square tests to evaluate the association between these variables and the percent mark removal. Variables from bivariate testing with $p<0.1$ were separately entered into generalized estimating equation models which evaluated the outcomes of mark removal and culture positivity of objects while accounting for clustering by nursing home. Model variables were retained at $\alpha < 0.05$ (ProcGENMOD, SAS v9.2, Cary, NC). In addition, we tested the correlation between the percent of MRSA positive objects and percent cleaning mark removal across all nursing homes using Pearson's correlation coefficient. We performed a t-test to compare length of stay for MRSA positive vs. negative patients by nursing home.

RESULTS

We obtained 500 swabs (50 per nursing home) and evaluated 577 (~60 per nursing home) cleaning marks from 10 nursing homes (23 marks were placed but not evaluated due to objects' movement). Descriptive characteristics for nursing homes are shown in Table 1. Nursing homes had a median of 112 beds (range 24–206) and 458 annual admissions (142–1894). Median MRSA admission prevalence was 12% (4–31%), and median MRSA point prevalence was 24% (7–51%). Six of 10 nursing homes were in the high MRSA delta prevalence group (absolute difference >10 between MRSA admission and point prevalence). No difference was found in mean length of stay for MRSA positive vs. negative residents (350 vs. 357 days; t-test, p=0.89).

Environmental Sampling for MRSA

Among the 500 objects cultured, 16% (78) were MRSA positive (range 0–46% across facilities). We found a higher proportion of MRSA-positive objects in the high vs. low MRSA delta prevalence nursing home groups (19% vs. 10% MRSA-positive objects, p=0.005).

Evaluation of Routine Cleaning

Overall, only 22% of marks were removed (129/577; range 11–31% across facilities). Marks were removed twice as often among flat vs. non-flat objects (35% vs. 17%, $p<0.001$). Cleaning mark removal was similar among high vs. low delta prevalence groups (23% vs. 21%, p=0.62). We did not find a correlation between mark removal and MRSA positive objects at individual nursing homes (Pearson's coefficient −0.088).

Survey on Infection Control and Environmental Cleaning Policies

Our survey on infection control and environmental cleaning policies was completed by all 10 participating nursing homes (Table 1). Contact precautions were applied to residents with active MRSA infection in 80% (8 of 10) of nursing homes and to residents with MRSA infection or colonization in 10%. One nursing home did not employ contact precautions in any circumstance. Reasons provided for resident restriction from common areas included active MRSA infection (or other multi-drug resistant pathogen or Clostridium difficile infection; 30%), draining wounds (30%), evidence of respiratory infection with MRSA (20%), and active cough (10%). One nursing home did not restrict residents from common areas due to infection or related symptoms. Contact precautions were discontinued for

MRSA-positive residents based upon physician order (30%), nursing determination of symptom resolution (30%), completion of antibiotics (10%), or both completion of antibiotics and symptom resolution (30%). Screening for MRSA was not performed in any nursing home. The mean percent effort administrators devoted to infection control and prevention was 38% (range 10%–100%).

For environmental cleaning, 80% of nursing homes directly employed cleaning staff. The mean number of rooms assigned per cleaning staff member was 20 (range 12–27) while the mean time spent cleaning per room was reported to be 21 minutes (range 7–45). Fifty percent of nursing homes used bleach to clean, 40% used quaternary ammonium, and 10% used another product (tri-sodium phosphate, marketed as “Spic n Span”). For residents with C.difficile infection, bleach was used for routine and discharge cleaning in 90% of nursing homes, and for discharge cleaning only in 10%. For residents with MRSA, other multi-drug resistant pathogens, or C.difficile, rooms were cleaned last each day in 50% of nursing homes. On average, common rooms were cleaned 2.5 times per day (range 1–3).

Bivariate Analyses of Environmental MRSA and Cleaning Marks

In bivariate analysis, the presence of MRSA-positive objects was found to be significantly associated with nursing homes in the high MRSA delta prevalence group (chi-square = 7.94, p=0.004). The presence of MRSA-positive cultures was not associated with object type, whether the object was flat, room type, facility median length of stay, facility proportion of non-removed cleaning marks, or the amount of time surfaces and objects were exposed to cleaning products.

Among continuous variables, we found that MRSA-positive objects were associated with higher MRSA admission prevalence (per 10% increase; OR =1.5; p<0.001), lower percentage of administrator time (per 10% effort) dedicated to infection control (OR = 1.1; p=0.006), higher number of rooms assigned per cleaning staff member (OR = 1.1; p<0.001), less time (per 10 minute interval) spent cleaning per room (OR = 1.8; p<0.001), and less frequent common room cleaning per day (OR = 1.4; p=0.04).

In a similar analysis, we found that persistence of cleaning marks was associated with object type (percent persistent marks by object: 59% for counters, 62% for tables, 80% for rehabilitation equipment, 84% for chairs, 86% for handrails and 87% for hallway objects; p<0.001), with whether the object was flat (64% vs. 84% persistent marks for flat vs. non-flat objects, respectively; p<0.001), and with room type (percent persistent marks by room: 59% for nurse stations, 70% for activity rooms, 75% for lounges and patios, 76% for dining rooms, 81% for rehabilitation rooms, and 87% hallways; p<0.001). There was a trend toward significant association of persistent cleaning marks with higher MRSA admission prevalence (per 10% increase; OR = 1.2, p=0.06).

Persistence of cleaning marks was not associated with MRSA delta prevalence group, facility median length of stay, the percent of administrator effort dedicated to infection control, the number of rooms assigned per staff member for cleaning, the time spent cleaning per room, the time surfaces were exposed to cleaning agents, or the frequency of common room cleaning.

Multivariate Analyses of Environmental MRSA and Cleaning Marks

In the multivariate model predicting MRSA-positive objects (Table 2), MRSA-positive objects were associated with nursing homes in the high MRSA delta prevalence group, nursing homes where less time was spent cleaning per room, and with nursing homes with less frequent cleaning of common rooms. In our multivariate model predicting persistence of cleaning marks, lack of removal was highest for hallway objects, rehabilitation equipment

and chairs, compared to tables and counters. For every 10% increase in MRSA admission prevalence, there was a 22% increase in the likelihood that a cleaning mark persisted.

DISCUSSION

To the best of our knowledge, this is one of the first studies of MRSA environmental contamination in nursing homes that examined associations between MRSA contamination, cleaning quality, and infection control practices. We found that environmental contamination with MRSA was common, especially in nursing homes that had a large difference between point prevalence compared to what is imported from admitted patients (admission prevalence). Our findings suggest that environmental contamination with MRSA may contribute to the burden of MRSA in nursing homes.

Nursing homes face unique infection control challenges. Due to the importance of maintaining a home-like environment, residents in nursing homes often freely interact in common areas regardless of MRSA status. In turn, the common spaces where residents mingle, including dining rooms, recreation rooms, and rehabilitation rooms, may be much more relevant to infection control and prevention efforts than in the traditional hospital setting. Improving environmental cleaning in nursing homes may be a practical alternative to more restrictive methods, such as contact isolation policies, used in hospitals.

Environmental contamination with MRSA was found in approximately 1 in 6 objects in nursing home common areas. However, the frequency of contaminated objects varied across nursing homes. Two nursing homes had no positive cultures, while almost half of common area objects in another nursing home tested positive for MRSA. This variation indicates that certain facilities may have specific infection control strategies in place that effectively limit MRSA contamination and potential transmission between residents. Levels of environmental MRSA were significantly higher in nursing homes with greater differences in overall MRSA prevalence compared to imported levels, suggesting that contamination of fomites and surfaces in common areas may play a role in MRSA spread in nursing homes. Such contamination may be limited by improving cleaning practices in these areas.

We found that infection control practices, such as implementation of contact precautions for MRSA-positive residents, were not associated with MRSA contamination of common room objects. This evaluation may be limited by the relative homogeneity of certain practices in these ten nursing homes. In this study, 90% of nursing homes placed patients with MRSA infection on contact precautions. On the other hand, 80% did not restrict social interaction for residents who were only colonized, not infected, with MRSA. Further, criteria for discontinuation of contact precautions for residents with MRSA infection varied substantially, from completion of antibiotics to individual physician orders. Additional studies are needed to evaluate how infection control practices may be optimized to limit transmission without unduly hindering residents' social activities and mental and physical well-being.

In contrast, we did find a significant association between MRSA contamination and cleaning practices. MRSA-positive objects were associated with the amount of time spent cleaning each room and with the frequency of common room cleaning. These measures are likely indicators of the thoroughness or quality of cleaning, which could impact whether MRSA is successfully removed from environmental sources. Increasing the time spent cleaning per room or the number of times common rooms are cleaned per day may be effective changes for nursing homes with significant MRSA transmission among residents. Studies directly assessing this question are needed.

Removal of cleaning marks from common areas was low and relatively uniform across nursing homes, where 1 in 5 marks were removed on average. Cleaning mark removal was similar between the low and high delta prevalence nursing home groups and was not correlated to levels of environmental MRSA. This finding may be partly due to the fact that cultures and marks were not always sampled from the exact same location on each object. More likely, mark removal in our investigation was uniformly poor (11–31% of marks removed across nursing homes) and below the threshold needed to demonstrate an association. It is possible that higher levels of mark removal of 70–100% may be needed to consistently remove MRSA from objects and surfaces, as previously shown.[16] Similar to prior work, we found that cleaning was dependent on the type of object. As in other studies,[16,21,23] objects with broad, flat surfaces (such as tables and counters) were more commonly cleaned. In contrast, objects with odd shapes or contours, such as chairs, handrails and doorknobs, were not cleaned as thoroughly or as often, although these objects are frequently touched.

We also found that persistence of cleaning marks was associated with higher MRSA admission prevalence, suggesting that cleaning may be insufficient in facilities that admit higher risk residents. This is worrisome since ideally cleaning measures would be more robust in nursing homes that admit a high fraction of residents carrying multi-drug resistant pathogens. These results suggest that cleaning-based interventions may need to focus training on high risk areas, objects, and even high risk nursing homes. Evaluating cleaning mark removal and providing feedback to environmental services staff has been shown to improve cleaning quality and reduce environmental contamination with MRSA and other multi-drug resistant pathogens in hospitals,[16,22–23] and a similar approach may be effective in nursing homes.

Our study has several limitations. While a substantial difference in MRSA point and admission prevalence may result from transmission, we did not serially swab residents to determine if transmission actually occurred. Higher MRSA point prevalence may also result from unmasking of prior colonization, suggested by the association between having a history of MRSA and carriage of MRSA at point prevalence. Furthermore, our study of 10 nursing homes is limited by its sample size. Nevertheless, it is the largest study, to our knowledge, evaluating the association between MRSA prevalence among nursing home residents and environmental contamination. Our study also did not allow us to determine a causal relationship between these factors. We did not perform genetic testing of environmental MRSA strains; however, previous studies have shown that environmental MRSA strains are often highly genetically similar to strains carried by patients.[28–30] Finally, we do not know the threshold of cleaning quality that must be achieved to reduce MRSA contamination, although our findings suggest that increasing the time spent cleaning per room and the frequency of common room cleaning may improve cleaning quality and reduce MRSA contamination levels. We were not able to determine which product is best for environmental cleaning, but this question may be an appropriate topic for future studies. Cleaning practices were obtained from surveys administered to environmental services staff, but were in agreement with on-site observations. While environmental contamination is only one possible reason for differences in MRSA prevalence in nursing homes, it may be particularly important in this setting due to the need for less stringent infection control policies. Moreover, environmental contamination represents a modifiable risk factor, since improved cleaning can reduce contamination levels.

In summary, we found that environmental MRSA contamination was highly variable among 10 nursing homes, and higher MRSA contamination levels among nursing home fomites were associated with a higher number of MRSA carriers at point prevalence versus admission prevalence, which may suggest that MRSA contamination contributes to

transmission. Interventions to reduce environmental MRSA in nursing home should consider increasing the time spent cleaning per room and improving cleaning in common areas where residents routinely congregate.

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Table 1

Descriptive Characteristics of 10 Orange County Nursing Homes (NH)

Facility Characteristic	All NH (N=10)	Low Delta Prevalence (N=4)	High Delta Prevalence (N=6)
	Median (Range)		
Number of Beds *	112 (24–206)	112 (24–138)	121 (59–206)
Annual Admissions	458 (142–1894)	377 (262–1894)	579 (142–1487)
Average Length of Stay in days (±SD)			
MRSA carriers	350 (728)	495 (1066)	302 (571)
MRSA non-carriers	357 (694)	348 (699)	364 (690)
MRSA Admission Prevalence	12% (4–31)	16% (4–22)	10% (4–31)
MRSA Point Prevalence	24% (7–51)	12% (7–30)	28% (19–51)
Infection Control Practices	Number (Percent) of Facilities †		
Management %Effort for Infection Control (Median (Range))	38% (10–100)	15% (10–50)	50% (10–100)
Contact Precautions Applied for MRSA			
Only for active infection	8 (80%)	2 (50%)	6 (100%)
Active infection or colonization	1 (10%)	1 (25%)	0 (0%)
Contact precautions not used	1 (10%)	1 (25%)	0 (0%)
Contact Precautions Discontinued for MRSA Infection			
When antibiotics completed	1 (10%)	0 (0%)	1 (17%)
When MRSA-related symptoms resolved	3 (30%)	1 (25%)	2 (33%)
When antibiotics completed and symptoms resolved	3 (30%)	1 (25%)	2 (33%)
According to physician's orders	3 (30%)	2 (50%)	1 (17%)
Screening Asymptomatic Residents for MRSA	0 (0%)	0 (0%)	0 (0%)
Resident Restrictions from Common Areas			
Active Cough	1 (10%)	1 (25%)	0 (0%)
MRSA in sputum	2 (20%)	1 (25%)	1 (17%)
Uncontained or draining wounds	3 (30%)	0 (0%)	3 (50%)
Active infection with MRSA, MDROs ≠ or C.difficile	3 (30%)	1 (25%)	2 (33%)
Residents not restricted	1 (10%)	1 (25%)	0 (0%)

Facility Characteristic	All NH (N=10)	Low Delta Prevalence (N=4)	High Delta Prevalence (N=6)
Environmental Cleaning Practices	**Median (Range)**		
Assigned Rooms per Cleaning Staff Member	20 (13–27)	20 (12–27)	20 (13–25)
Time Spent Cleaning per Room (min)	18 (7–45)	17 (7–30)	19 (14–45)
Frequency of Common Room Cleaning (per day)	2.5 (1–3)	3 (2–3)	2 (1–3)
Product Used for Routine Cleaning (N (%) of facilities)			
Bleach	5 (50%)	2 (50%)	3 (50%)
Quaternary Ammonium	4 (40%)	1 (25%)	3 (50%)
Other (tri-sodium phosphate)	1 (10%)	1 (25%)	0 (0%)
Contact Precaution Rooms Cleaned Last	5 (50%)	2 (50%)	3 (50%)

[*] T-tests were used to compare low and high delta nursing homes for the following characteristics: number of beds (p=0.47); annual admissions (p=0.99); and average length of stay for MRSA carriers (p=0.77) and non-carriers (p=0.96).

[†] N = 10 nursing homes

[≠] Multi drug resistant organisms

Table 2

Multivariate Analysis of MRSA Positive Objects and Cleaning Mark Non-Removal

Outcome: MRSA Positive Culture			
Variable	**OR**	**95% Confidence Interval**	**p-value**
High MRSA Delta Prevalence Group *	2.8	(1.4, 5.9)	0.005
Less Time Spent Cleaning per Room (per 10 minute reduction)	2.9	(1.5, 5.4)	<0.001
Lower Frequency of Common Room Cleaning	1.5	(1.1, 2.0)	0.01
Outcome: Non-Removal of Cleaning Mark			
Variable	**OR**	**95% Confidence Interval**	**p-value**
Object Type			
Tables	reference		
Hallway Objects	4.2	(2.4, 7.4)	<0.001
Chairs	3.5	(1.6, 7.3)	0.001
Rehabilitation Equipment	2.4	(1.4, 4.3)	0.002
Counters	0.9	(0.4, 1.9)	0.77
MRSA Admission Prevalence †	1.2	(1.0, 1.4)	0.04

* High MRSA delta prevalence group was defined as nursing homes where the absolute difference in MRSA admission and point prevalence was 10% or higher

† MRSA admission prevalence is expressed per 10% increase in prevalence