Infection Control & Hospital Epidemiology (2024), **45**, 1442–1447
doi:10.1017/ice.2024.129

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Original Article

Microbial burden on environmental surfaces in long-term care facilities: a quantitative analysis

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Abstract

Background: We conducted a quantitative analysis of the microbial burden and prevalence of epidemiologically important pathogens (EIP) found on long-term care facilities (LTCF) environmental surfaces.

Methods: Microbiological samples were collected using Rodac plates (25cm2/plate) from resident rooms and common areas in five LTCFs. EIP were defined as MRSA, VRE, C. difficile and multidrug-resistant (MDR) Gram-negative rods (GNRs).

Results: Rooms of residents with reported colonization had much greater EIP counts per Rodac (8.32 CFU, 95% CI 8.05, 8.60) than rooms of non-colonized residents (0.78 CFU, 95% CI 0.70, 0.86). Sixty-five percent of the resident rooms and 50% of the common areas were positive for at least one EIP. If a resident was labeled by the facility as colonized with an EIP, we only found that EIP in 30% of the rooms. MRSA was the most common EIP recovered, followed by C. difficile and MDR-GNR.

Discussion: We found frequent environmental contamination with EIP in LTCFs. Colonization status of a resident was a strong predictor of higher levels of EIP being recovered from his/her room.

(Received 26 May 2023; accepted 2 July 2024; electronically published 31 October 2024)

Background

As the world population is aging, the number of people aged 65 and older in the United States are projected to nearly double in size from 49 million in 2016 (15% of the population) to 81 million in 2040 (22% of the population).[1,2] With the significant aging of the population, there are now over 1.7 million residents in the 16,000 US nursing homes and more people in long-term care facilities (LTCFs) than in acute-care hospitals, which highlights the importance of infection prevention in these facilities.[1,3] LTCFs, including nursing homes, skilled nursing facilities, and assisted living facilities, provide a variety of services, both medical, nursing and personal care, to people who need ongoing care over an extended period.[1,3]

About 15% of nursing home residents acquire an infection and infection (eg, sepsis) is one of the top 5 causes of death in nursing homes.[1,3] This is attributable to predisposing comorbidities, severity of illness, weakened immune system, functional and cognitive impairment, frequent use of indwelling devices (eg, urinary catheter), recent hospitalization, frequent antibiotic use, potential transmission through group activities and therapeutic sessions, and difficulties in adhering to infection prevention guidelines due to multiple tasks of staff, limitation of funds, and less trained/experienced staff.[1,3]

Nursing home patients have a high prevalence of colonization. In one prospective study of newly admitted patients in six nursing homes in Michigan, more than 50% (56.8%) were colonized with multidrug-resistant organisms (MDROs) at enrollment, including 16% with methicillin-resistant *Staphylococcus aureus* (MRSA); 33% with vancomycin-resistant *Enterococcus* (VRE), and 32% with multidrug-resistant Gram-negative rods (MDR-GNRs).[4] The high prevalence of MDROs in nursing home residents is linked, in part, to environmental surface contamination.[5] McKinnell et al. found environmental MDRO contamination in 74% of resident rooms and 93% of common areas when half of the residents harbored an MDRO.[5]

It has been well documented that hospital environmental surfaces play an important role in the transmission of MDROs such as MRSA and VRE.[6] Since there are few studies focused on contaminated environmental surfaces in LTCFs, we conducted a quantitative analysis of the microbial burden and prevalence of epidemiologically important pathogens (EIP) found on LTCF environmental surfaces.

Methods

A convenience sample of 5 LTCF in North Carolina was studied. The LTCF operated with 57–173 beds. Microbiological samples were collected using Rodac plates (25cm^2/plate) from resident

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Cite this article: Rutala WA, DiBiase LM, Powell AW, *et al.* Microbial burden on environmental surfaces in long-term care facilities: a quantitative analysis. *Infect Control Hosp Epidemiol* 2024. 45: 1442–1447, doi: 10.1017/ice.2024.129

rooms and common areas in five, North Carolina LTCFs in 2016. Each LTCF was sampled twice, separated by 2–22 days, and 30 total rooms were sampled (5 LTCFs; 4 resident rooms and 2 common rooms per LTCF). Five Rodac plates containing Dey-Engley neutralizing agar (Becton Dickinson & Company, Sparks, MD) were used per site to evaluate vegetative bacteria and five *Clostridioides difficile* Selective Agar plates were used per site to recover *C. difficile*. The DE Agar plates were incubated at 37ºC for 48 hours and the *C. difficile* Selective Agar plates (not prereduced) were incubated anaerobically (Anaeropack; Mitsubishi Gas Chemical) at 37º for 48 hours for *C. difficile*. At each facility, five Rodac samples per environmental site were collected from eight different environmental surface sites from the room of an ambulatory resident (not bedridden) reported to be colonized with an EIP, as well as from a room of a resident reported to be non-colonized. The colonization status of the resident was not confirmed by the investigators (eg, by medical record review). EIP were defined as MRSA, VRE, *C. difficile,* and MDR-Gram-negative rods (eg, *Klebsiella*). When evaluating gram-negative rods (GNRs), morphologically identical GNRs per site were identified with API (Biomerieux, Durham, NC) and Kirby-Bauer antibiotic susceptibility testing was performed on GNR isolates. An MDR GNB was defined at being resistant to 3 or more major classes of antimicrobials. No molecular testing to assess for relatedness of isolates was performed. In addition, five samples per environmental site from eight different environmental surfaces (eg, floors, cabinet faces, countertops, refrigerators, chairs, tables, hand rails, etc.) were collected from two common areas in the facility. Of the 10 common areas, 6 rooms had chairs and tables and no dining, 3 had dining areas, and one room was for visiting, a library and a fish and bird room. If the intended site was not available, an alternative site was chosen. Data were analyzed for each environmental site sampled in a resident room or common area for the presence of total colony-forming units (CFU) of bacteria, the mean CFU per Rodac, the total EIP CFU by site, mean EIP CFU per Rodac and presence of at least one EIP per room. The study was approved by the UNC Institutional Review Board.

Results

Table 1 summarizes the data on total CFU and EIP CFU recovered from environmental sites by reported colonization status of the resident. Rooms of residents with reported colonization had much greater EIP CFU per Rodac (8.32, 95%CI 8.05, 8.60) than rooms of non-colonized residents (0.78, 95% CI 0.70, 0.86). If a resident was labeled by the facility as colonized with an EIP, we only found that EIP in 30% of the rooms. MRSA was the most common EIP recovered from Rodacs (3,099 CFUs), followed by *C. difficile* (863 CFUs) and MDR-GNR (187 CFUs). With the exception of MRSA, very few EIP were recovered from the common areas sampled at these LTCFs (Table 2).

Sixty-five percent of the resident rooms and 50% of the common areas were positive for at least one EIP (Table 3). In resident rooms, environmental sites contaminated with EIP in greater than 15% of the samples collected were the closet door, bathroom floor, and overbed table. The floor and blackboard frame in the common rooms were contaminated with EIP ≥25% of the samples collected (Table 4). The total CFU of EIP recovered from the five LTCFs varied greatly: LTCF 1-1,462 EIP, LTCF 2-3 EIP, LTCF 3-2 EIP, LTCF 4-1,321 EIP, and LTCF 5-1,389 EIP. Some resident rooms (8/20, 40%) had substantial EIP contamination of environmental surfaces (eg, one resident room 850 CFU EIP, mostly *C. difficile* [848]) but 35% (7/20) had no EIP recovered and 25% (5/20) had less than 10 EIP recovered from environmental surfaces. MRSA or *C. difficile* was recovered from 55% (11/20) of the LTCFs resident rooms; 50% (10/20) were contaminated with MRSA; and 30% (6/20 resident rooms) were contaminated with *C. difficile*. Of the 861 Rodacs collected from resident rooms, 34 (4.0%), 51 (6.0%), 1 (0.1%) and 10 (1.1%) were positive for *C. difficile*, MRSA, VRE and MDR-GNR, respectively.

The characteristics of study LTCFs are displayed in Table 5. None of the study LTCFs provided care for ventilated patients. Of note, two LCRFs were for profit and three were not-for profit. The mean of EIP found on surfaces from non-profit versus for-profit LTCF was 489 versus 1325, but LCTF 1 (non-profit) had similar levels of EIP as the two for-profit LCTF (ie, 1,321 and 1,389).

Discussion

Patient colonization and environmental contamination with multidrug-resistant organisms are common in LTCFs. In most nursing homes, approximately 50% of residents are colonized with MDROs of clinical and public health significance.[4,5] The high prevalence of EIP among residents in LTCF likely represents the most common source for contamination of EIP on environmental surfaces.[5] Our data as well as other studies[5] demonstrate that environmental surfaces can be a reservoir and source for EIP as environmental surfaces in resident rooms and common areas are commonly contaminated with EIP.[5]

Contaminated environmental surfaces and noncritical patient care items play an important role in the persistence and transmission of several key healthcare-associated pathogens including MRSA, VRE, *Acinetobacter*, norovirus, *Pseudomonas aeruginosa*, and *C. difficile*.[6] More recently, environmental contamination has been demonstrated to be associated with transmission of Ebola, mpox and *Candida auris*.[7]

All of these pathogens are capable of surviving in the environment for days to weeks (in some cases [*C. difficile* spores] months), frequently contaminate the environmental surfaces in rooms of colonized or infected patients, transiently colonize the hands and/or gloves of healthcare personnel, which may lead to transmission by healthcare personnel, and cause outbreaks in which environmental transmission was deemed to play a role.[6,8] Importantly, a study by Stiefel et al. demonstrated that contact with the environment was just as likely to contaminate the hands of healthcare providers as was direct contact with the patient.[9] Studies have also shown a significant association between microbial burden and HAI risks.[10,11] Further, admission to a room in which the previous patient had been colonized or infected with MRSA, VRE, *Acinetobacter* spp. or *C. difficile*, has been shown to be a significant risk factor for the newly admitted patient to develop colonization or infection. For example, the risk of acquiring *C. difficile* infection (CDI) after admission to a room where the prior occupant was without CDI was 4.6%, whereas 11.0% if the prior occupant had CDI.[12] This infection risk from the prior occupant may be less common in nursing homes than hospitals due to the longer duration of stay of the residents, but the infection transmission factors (eg, environmental contamination, hand contamination, environmental survival, suboptimal disinfection) are present. Lastly, improved terminal cleaning and disinfection of rooms[13] as well as "no touch" room decontamination methods[8,13] has led to a decreased rate of infection in patients subsequently admitted to the room where the prior occupant was colonized or infected with an EIP. Unfortunately, "no touch" room

https://doi.org/10.1017/ice.2024.129 Published online by Cambridge University Press

Table 1. Total colony-forming units (CFU) and epidemiologically important pathogens (EIP) recovered from environmental sites in resident rooms, stratified by colonization status of resident, in five long-term care facilities in North Carolina

	Non-colonized resident rooms					Colonized resident rooms				
Site	Number of Rodac sampling	Total CFU by site	Mean CFU per Rodac	Total EIP by site	Mean CFU of EIP per Rodac	Number of Rodac sampling	Total CFU by site	Mean CFU per Rodac	Total EIP by site	Mean CFU or EIP per Rodac
Bathroom Floor	54	8175	151	35	0.65	55	8227	149.58	1820	33.09
Bed Rail	48	5020	105	20	0.42	45	7176	159.47	614	13.64
Over Bed Table	48	5953	124	24	0.5	55	5123	93.15	123	2.24
Nightstand	55	4934	90	1	0.02	49	6081	124.1	223	4.55
Sink	55	5078	92	251	4.56	49	2684	54.78	371	7.57
Side Table	45	2477	55	4	0.09	34	3023	88.91	3	0.09
Chair	35	2008	57	1	0.03	44	2945	66.93	361	8.2
Head of Bed	15	799	53	0	0	20	1211	60.55	3	0.15
Windowsill	5	175	35	0	0	5	361	72.2	0	0
Foot of Bed	35	779	22	1	0.03	45	1127	25.04	20	0.44
Bed Remote Control	3	56	19	0	0	3	64	21.33	0	0
Door	25	157	6	0	0	14	98	7	16	1.14
Closet Door	10	65	7	0	0	10	55	5.5	7	0.7
Resident Room Total	433	35676	82	337	0.78	428	38175	89.19	3561	8.32

CFU, colony-forming units; EPI, epidemiologically important pathogens.

Table 2. Frequency of environmental surface contamination with epidemiologically important pathogens (EIP) in resident rooms and common rooms in five long-term care facilities in North Carolina

	Resident rooms			Common rooms			Overall total		
EIP Identified	Number of positive Rodac with EIP	Total CFU of EIP on positive Rodacs	Mean CFU of EIP per positive Rodac	Number of positive Rodac with EIP	Total CFU of EIP on positive Rodacs	Mean CFU of EIP per positive Rodac	Number of positive Rodac with EIP	Total CFU of EIP on positive Rodacs	Mean CFU of EIP per positive Rodac
C. difficile	34	856	25.18	5	7	1.40	39	863	22.13
MRSA	51	2998	58.78	15	101	6.73	66	3099	46.95
VRE	1	1	1.00	1	7	7.00	2	8	4.00
MDR-GNR	10	43	4.30	7	144	20.57	17	187	11.00

MDR-GNR, multidrug-resistant Gram-negative rods; MRSA, methicillin-resistant *Staphylococcus aureus*; VRE, vancomycin-resistant enterococci.

decontamination technologies may not be attainable (eg, financial restrictions, inadequate staffing) to most LTCF. Thus, surface disinfection of noncritical environmental surfaces and medical devices (defined as those that contact intact skin) is one of the important infection prevention strategies to prevent pathogen transmission.[14]

This infection risk from environmental surfaces is not surprising as multiple studies have demonstrated that environmental surfaces and objects in rooms are frequently not properly cleaned and disinfected.[13,14] Our data in LTCFs demonstrated that EIP were recovered from many environmental surfaces to include the bathroom floor, bed rail, over-the-bed table, sink, and chair. MRSA (3,099 MRSA CFUs) and *C. difficile* (863 *C. difficile* CFUs) were most commonly recovered from environmental surfaces in resident rooms and common areas. Sixty-five percent of resident rooms and 50% of common rooms were contaminated with at least one EIP (Table 3), which is similar to other investigations.[5] Approximately 11% (96/861) of the Rodac samples from resident rooms were positive for EIP (mostly *C. difficile* [34] and MRSA [51]), and 6.6% (28/420) of the Rodac samples from community rooms were positive for EIP (eg, *C. difficile* [5] and MRSA [15]). Gontjes et al found a higher rate of MDRO contamination (13.4%) of high-touch common area and rehabilitation gym surfaces in nursing homes.[15] Other investigators found a prevalence of 28.6% (74/259) of MRSA on environmental surfaces from nursing homes in Ohio.[16]

This environmental surface contamination facilitates transfer from surfaces to residents via healthcare providers' hands from resident contact or by residents touching contaminated environmental surfaces. A resident could also become colonized by

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Table 3. Number of rooms in long-term care facilities with at least one epidemiologically important pathogens (EIP)

	Number of rooms positive for at least 1 EIP	Number of rooms sampled for EIP	Frequency, %
Resident Rooms			
Any EIP	13	20	65
MRSA	10	20	50
VRE	3	20	15
C. difficile	6	20	30
MDR-GNR	7	20	35
Common Areas			
Any EIP	5	10	50
MRSA	3	10	30
VRE	1	10	10
C. difficile	2	10	20
MDR-GNR	2	10	20
Total Rooms			
Any EIP	18	30	60
MRSA	13	30	43
VRE	4	30	13
C. difficile	8	30	27
MDR-GNR	9	30	30

EIP, epidemiologically important pathogens; MDR-GNR, multidrug-resistant Gram-negative rods; MRSA, methicillin-resistant *Staphylococcus aureus*; VRE, vancomycin-resistant enterococci.

Table 4. Frequency of environmental sites positive for epidemiologically important pathogens (EIP) in resident rooms and common rooms in five long-term care facilities in North Carolina

Environmental site	Number of samples positive for any EIP	Number of samples taken	Frequency, %
Resident Rooms			
Closet Door	5	20	25.0
Bathroom Floor	22	109	20.2
Over Bed Table	17	103	16.5
Chair	10	79	12.7
Nightstand	10	104	9.6
Sink	10	104	9.6
Bed Rail	8	93	8.6
Foot of Bed	6	80	7.5
Head of Bed	2	35	5.7
Side Table	3	79	3.8
Door	1	39	2.6
Windowsill	0	10	0.0
Bed Remote Control	0	6	0.0
Resident Room Total	94	861	10.9
Common Rooms			
Floor	19	44	43.2
Blackboard Frame	1	4	25.0
Table	2	90	2.2
Countertop	1	60	1.7
Chair	1	100	1.0
Sink	0	20	0.0
Ice Maker	0	5	0.0
Computer Table	0	5	0.0
Handrail	0	20	0.0
Piano	0	5	0.0
Side Table	0	30	0.0
Entry Sill (low wall)	0	5	0.0
Door	0	10	0.0
Snack Machine	0	5	0.0
Cabinet Face	0	10	0.0
Refrigerator	0	10	0.0
Wall	0	5	0.0
Common Rooms Total	24	428	5.6
Overall Total	118	1289	9.15

EIP, epidemiologically important pathogens.

self-inoculation by direct contact with a contaminated environmental surface. In fact, Patel et al. found that contamination of the patient room environment correlates with patient colonization in postacute care facilities[17] and Cassone et al. identified environmental panels as a proxy for patient colonization.[18]

Surfaces are not regularly disinfected in healthcare facilities (including LTCFs), and these surfaces may be important in transmission of healthcare-associated pathogens. For example, a recent study found that the overall cleaning rates for environmental surfaces in LTCFs was 42% for all surfaces and 49% for high-touch surfaces and the cleaning duration was 13.6 minutes.[19] Despite the limitations of evidence in LTCFs, it is clear that EIP are commonly present on environmental surfaces, the frequency and thoroughness of cleaning and disinfection in LTCFs is suboptimal, and improvements in surface disinfection are needed in LTCFs to deliver the safest possible health care.

While the levels of EIP on environmental surfaces varied, some patient's rooms were heavily contaminated. In addition, if a resident was labeled by the facility as colonized with an EIP, we only found that EIP in 30% of the rooms. This mismatch of EIP reported for residents versus recovered on environmental surfaces may be attributable to co-colonization.[20] Frequent contact with contaminated environmental surfaces in resident rooms and common areas necessitates improved hand hygiene and daily, as well as postdischarge, environmental surface disinfection. This burden of EIP on environmental surfaces in resident rooms and common areas requires standardized and comprehensive cleaning and disinfection that address known barriers in LTCF (eg, resident present during cleaning and disinfection, semi-private rooms, remove room clutter)[19] in resident rooms and common areas.[19,21] Previous studies have demonstrated that daily disinfection of surfaces in CDI and MRSA isolation rooms reduced acquisition of the pathogens on hands after contacting high-touch surfaces and

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Table 5. Information about studied long-term care facilities

TC	Number of beds	Acute rehab facility	Chronic mechanical ventilation provided to patients	Non-profit or for-profit LTCF	Facility participates in Medicare	Facility participates in Medicaid	Facility is CCRC
1	107	Yes	No	Non-Profit	Yes	Yes	No
2	57	Yes—for members	No	Non-Profit	Yes	No	Yes
3	173	Yes—for members	No	Non-Profit	Yes	No	Yes
4	120	Yes	No	For-Profit	Yes	Yes	No
5	131	Yes	No	For-Profit	Yes	Yes	No

CCRC, Continuing Care Retirement Center; LTCF, long-term care facilities.
Participates in Medicare = accepts payment/partial payment via Medicare insurance, federal health insurance for people 65 and older (medicare.gov).
Participates in Medicaid = accepts payment/partial payment via Medicaid insurance, a health insurance program for low-income individuals and families who cannot afford healthcare costs (ncdhhs.gov).
CCRC: Continuing care retirement communities, also known as CCRCs or life plan communities, are a long-term care option for older people who want to stay in the same place through different phases of the aging process. (aarp.org).

reduced contamination of hands of healthcare workers caring for the patients.[22]

There are limitations to this study. There was no molecular typing to match the environmental isolates with clinical isolates obtained from residents and a small number of LTCFs were studied. Additionally, since patient level risk factors for contamination were not obtained, we were not able to correlate cleaning and disinfection practices or patient medical conditions (eg, incontinent of feces) to elevated levels of environmental surface contamination.

While the mean of EIP found in for-profit LCTF was higher than non-profit LCTF, one non-profit LCTF had similar levels as the two for-profit LCTF. A higher frequency of hospitalization for infection has been reported in for-profit LCTF.[23] We were unable to assess other potential reasons for the disparities in levels of EIP (eg, staffing levels, physical plant, etc.) as this information was not collected.

Improved cleaning and disinfection of the contaminated environmental surfaces (ie, noncritical surfaces and medical equipment) is critical to reduce the risk of EIP transmission via environmental surfaces through contact with environmental surfaces and sharing common areas in nursing homes (eg, activity rooms). Further, bundles with evidence-based components (eg, resident and staff hand hygiene promotion, environmental disinfection, enhanced barrier precautions [ie, gown, glove with high-contact resident care activities]) may be necessary to reduce the risk of MDRO transmission in LTCFs.[1,14] Preventing healthcare-associated infection is critical for delivering safe and high-quality care in LTCFs and across the healthcare system.

Conclusions

We found varying levels of epidemiologically important pathogens on environmental sites at LTCFs. Colonization status of a resident was a strong predictor of higher levels of EIP being recovered from his/her room.

Financial support. This study was supported, in part, by the University of North Carolina Medical Center and the Statewide Program for Infection Control and Epidemiology.

Competing interests. Dr. Rutala is a consultant for Professional Disposable International (PDI) and Kinnos. Dr. Weber is a consultant for PDI and Germitec. All other authors have no disclosures.

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