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High Prevalence of Multidrug-Resistant Organism Colonization in 28 Nursing Homes: An "Iceberg Effect"

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a b s t r a c t

Objective: Determine the prevalence of methicillin-resistant Staphylococcus aureus (MRSA), vancomycin-resistant Enterococcus spp. (VRE), extended-spectrum beta-lactamase producing organisms (ESBLs), and carbapenem-resistant Enterobacteriaceae (CRE) among residents and in the environment of nursing homes (NHs).

Design: Point prevalence sampling of residents and environmental sampling of high-touch objects in resident rooms and common areas.

Setting: Twenty-eight NHs in Southern California from 2016 to 2017.

Participants: NH participants in Project PROTECT, a cluster-randomized trial of enhanced bathing and decolonization vs routine care.

Methods: Fifty residents were randomly sampled per NH. Twenty objects were sampled, including 5 common room objects plus 5 objects in each of 3 rooms (ambulatory, total care, and dementia care residents).

Results: A total of 2797 swabs were obtained from 1400 residents in 28 NHs. Median prevalence of multidrug-resistant organism (MDRO) carriage per NH was 50% (range: 24%-70%). Median prevalence of specific MDROs were as follows: MRSA, 36% (range: 20%-54%); ESBL, 16% (range: 2%-34%); VRE, 5% (range: 0%-30%); and CRE, 0% (range: 0%-8%). A median of 45% of residents (range: 24%-67%) harbored an MDRO without a known MDRO history. Environmental MDRO contamination was found in 74% of resident rooms and 93% of common areas.

Conclusions and Implications: In more than half of the NHs, more than 50% of residents were colonized with MDROs of clinical and public health significance, most commonly MRSA and ESBL. Additionally, the vast majority of resident rooms and common areas were MDRO contaminated. The unknown submerged portion of the iceberg of MDRO carriers in NHs may warrant changes to infection prevention and control practices, particularly high-fidelity adoption of universal strategies such as hand hygiene, environmental cleaning, and decolonization.

Health care-associated infections (HAIs) due to multidrugresistant organisms (MDROs) are a recognized threat to US public health.[1] Residents of nursing homes (NHs) are a population that deserves particular attention when evaluating HAI and MDRO epidemiology.[2-4] For example, emergence and spread of carbapenem-resistant Enterobacteriaceae (CRE) through the health care system has been linked to transfer of colonized NH residents to acute hospital settings for higher levels of care.[3] The Centers for Disease Control and Prevention (CDC) and the Centers for Medicare & Medicaid Services (CMS) have directed attention to infection prevention in the NH setting in an attempt to curb the spread of MDROs.[3,5]

Targeted infection prevention initiatives, such as contact precautions, can only be applied when MDRO colonization status is known.[6,7] Patients who asymptomatically carry MDROs often fail detection, either through lack of testing or poor communication of colonization status,

and can contribute to the spread of MDROs.[3] The unknown submerged portion of the "iceberg" of carriers has been shown to be a key determinant for disseminating MDROs from 1 health care setting to another within the health care system.8 Another determinant of MDRO spread is the amount of environmental contamination in patient rooms and common areas.[6,9,10]

Most previous MDRO investigations in NHs have involved small numbers of NHs and included Gram-positive pathogens, including methicillin-resistant Staphylococcus aureus (MRSA) and resistant Gram-negative bacteria, but not CRE.[11-22] Our recent investigation of 3 NHs in southern California identified MDRO colonization in 45% of NH residents, including MRSA in 26% and CRE in 1%.[14] We present here a larger assessment of MDRO colonization, the hidden "iceberg" of MDROs, and environmental contamination in 28 NHs.

The purpose of this investigation was to (1) evaluate the colonization prevalence of MRSA, vancomycin-resistant Enterococcus spp. (VRE), extended-spectrum beta-lactamase producing organisms (ESBLs), and CRE among NH residents in Southern California; (2) determine the unknown submerged portion of the "iceberg" of MDRO colonization among residents; and (3) determine the burden of MDRO environmental contamination in the patient care and common areas.

Methods

We conducted a point prevalence study of MDRO resident colonization and environmental contamination at 28 NHs in Southern California. Resident and environmental samplings were conducted as baseline measurements for a clinical trial, PROTECT: Protecting Nursing Homes From Infections and Hospitalization, a cluster-randomized trial comparing 2 quality improvement strategies: routine best practice bathing and a universal strategy of skin disinfection and nasal decolonization (https://clinicaltrials.gov/ct2/show/ NCT03118232). The PROTECT team provided supplies, logistics, and microbiologic testing. Swabbing was performed by trained nurses employed at each NH as a quality assessment and performance improvement (QAPI) evaluation of MDRO carriage among residents. This study was approved by the Institutional Review Board at University of California, Irvine.

Point Prevalence Sampling of NH Residents

A 1-day point prevalence sampling of 50 randomly selected NH residents at each of 28 participating facilities was conducted between September 2016 and February 2017. Residents were informed of the swabbing day for quality improvement purposes by the NH both verbally and in writing. Residents could decline participation, but no written consent was required because of the quality improvement purpose and the minimal risk procedure of nares and skin swab collection. The PROTECT team trained facility nurses on swabbing technique, and each nurse was required to show return demonstration of proper swab technique on the point prevalence day. A swabbing team consisting of the trained nurse who performed all swabbing, and 2 PROTECT project coordinators.

]Selection was based on a random sample of occupied beds (excluding hospice) until 50 residents were swabbed. NH nurses performed bilateral nares swabs for MRSA, as well as bilateral axilla/groin swabs, which were processed for MRSA, VRE, ESBLs, and CRE. All swabs (BBL CultureSwab; Becton Dickinson, Franklin Lakes, NJ) were premoistened prior to swabbing. Samples were deidentified at each NH prior to transport for processing and analysis.

Microbiologic Testing of Resident Swabs

Specimens were processed within 6 hours by the clinical microbiology laboratory at a university hospital. The media used and order of inoculation of swabs were as follows: MacConkey agar with a cefpodoxime disk (2 mg) for ESBLs, MacConkey agar with a meropenem disk (2 mg) for CRE, Campylobacter agar (10% sheep blood with vancomycin 10 mg, cephalothin 15 mg, trimethoprim 5 mg, polymyxin B 2.5 units, amphotericin B 2 mg) for VRE, and Spectra MRSA (Thermo Fisher Scientific, Lenexa, KS) for MRSA. Isolates on Spectra MRSA that were the typical morphology and denim blue color were not further confirmed. Isolates with atypical morphology or color on Spectra agar were confirmed as S aureus, and resistance was confirmed by a standardized disk diffusion test using cefoxitin disks. The identification of enterococci isolated on Campylobacter agar was verified by matrix-assisted laser desorption ionization time-of-flight mass spectrometry (MALDI-TOF).23 Isolates identified by the initial ESBL screen were further identified by MALDI-TOF and phenotypic testing for the presence of ESBL using disk diffusion with cefotaxime and ceftazidime with and without clavulanic acid, or using the VITEK2 GN-card (bioMérieux, Marcy-L'Etoile, France). Isolates identified as CRE by initial screen were further identified by MALDI-TOF and disk diffusion using meropenem, and, if needed because of a questionable result, the disk diffusion was repeated using meropenem, ertapenem, and imipenem or the VITEK2 GN-card. Isolates were classified as CRE if they were resistant to any carbapenem.

Environmental Contamination

We conducted environmental sampling of common areas and 3 resident rooms at each NH. Five common area objects (nursing station counter or cart, table, chair, hallway hand rail, drinking fountain or station) and 5 objects from each resident room (bedside table and bedrail, call button and TV remote, door knobs, light switch, and bathroom sink and rail and flush handle) were tested at each NH. Resident rooms were selected to include an ambulatory resident's room with a length of stay <30 days (ambulatory), a resident with Alzheimer's disease or related dementia (ADRD), and a bedbound resident (total care). The determination of ADRD, ambulatory, and total care status was confirmed by review of the medical record. Objects were swabbed qualitatively using prehydrated sponges (SpongeStick with neutralizing buffer; Biotrace 3M, St. Paul, MN). After collection, swabs were processed within 6 hours and placed in a Stomacher (Seward, Worthing, West Sussex, UK) with trypticase soy broth to homogenize the samples. Samples were then incubated for 18 to 24 hours and plated as above for the resident swabs.

Collection of NH Data

NH facility-level characteristics were collected from resident admission assessments in the CMS Minimum Data Set (MDS) for the most recent year available, 2016 (http://www.resdac.org/MDS/data_ available.asp), including the number of licensed beds, average daily census, mean length of stay, mean resident Elixhauser comorbidity score,24 and percentage of residents with specific Elixhauser comorbidities. NH data on total annual admissions, admissions per bed per year, occupancy ratio (proportion of available beds occupied by a resident), proportion of residents with Medicare as primary insurance, proportion of residents with Medicaid as primary insurance, average resource utilization group scores, mean activities of daily living index, and average acuity index were obtained for 2017 from LTCFocus.org. CMS Five-Star Quality Rating was obtained for 2017 from Medicare.gov's Nursing Home Compare website (https://www.medicare.gov/nursinghomecompare).

Collection of Clinical Data

Individual resident characteristics were collected from direct observation and review of the medical record using a standardized form. Medical devices (eg, central venous catheters, urinary catheters, drains, tubes, and other devices) and wounds were recorded by direct observation of each resident during sampling. Gastrointestinal devices included oral, nasal, or percutaneous devices. Prior knowledge of MDRO status was determined from review of the medical record and infection prevention surveillance records. Additional variables drawn from the medical record included age, gender, length of stay at time of swabbing, total care requirement (bed bound), incontinence, wounds, and presence of diabetes. Short-stay residents were defined as those with a length of stay 30 days from date of admission at time of swabbing. Long-stay residents were those with a length of stay >100 days from date of admission at time of swabbing.

Analysis of Results

For each NH, the prevalence of overall and individual MDROs (MRSA, VRE, ESBL, and CRE) were calculated as the proportion of swabbed residents who were colonized at any body site as well as each specific body site. The median, range, mean, and standard deviation of overall and individual MDRO prevalence were then calculated across NHs. The unknown submerged portion of the "iceberg" was defined as the percentage of patients found to harbor an MDRO whose colonization status was not documented in the medical record. In addition, we identified the proportion of residents with a known history of MDRO in whom an additional, previously undetected, MDRO pathogen was found.

To evaluate resident and NH characteristics associated with MDRO carriage, bivariate and multivariate analyses were performed using generalized linear mixed models clustering by resident and NH site. Analyses were performed for 5 outcomes: MRSA, VRE, ESBL, CRE, and any MDRO. Models accounted for clustering at the patient/resident and NH levels. Analyses

were performed for 5 outcomes: MRSA, VRE, ESBL, CRE, and any MDRO. Variables were retained in the models regardless of P value unless there was evidence of collinearity or the variable caused the models to not converge. All analyses were specified a priori and conducted using SAS, version 9.3 (SAS Institute, Cary, NC).

Table 1
Characteristics of Participating Nursing Homes (N = 28)

NH Facility-Level Characteristics	Median (Range) Across NHs, or n (%)
Mean age, y	76 (65, 86)
% male	43 (24, 57)
% long-stay*	76 (69, 89)
% Medicare	14 (0, 65)
% Medicaid	68 (9, 97)
% diabetes	41 (26, 54)
% chronic lung disease	20 (8, 67)
% renal insufficiency	13 (1, 25)
Licensed beds, n	99 (59, 299)
Mean daily census, n	103 (57, 232)
Occupancy ratio	1.0 (0.8, 1.0)
Mean length of stay, d	213 (183, 300)
Total annual admissions	468 (195, 1636)
Admissions per bed per year, n	4 (2, 13)
Mean Elixhauser comorbidity score	3 (2, 6)
Mean ADL Index	12 (7, 15)
Mean RUG-III index	1 (1, 1)
CMS Five-Star Quality Rating (2017)	4 (1, 5)
1 star, n (%)	1 (4)
2 star, n (%)	6 (21)
3 star, n (%)	6 (21)
4 star, n (%)	5 (18)
5 star, n (%)	10 (36)

RUG-III, Resource Utilization Groups version III.
*% long-stay refers to the proportion of residents with a length of stay >100 days.

Results

NH Point Prevalence

Characteristics of the participating NHs are found in Table 1. More than half of the participating facilities (54%) were rated 4 or 5-star on the CMS quality rating scale. A total of 2797 swabs were obtained from 1400 residents in 28 NHs, including 1397 nares swabs and 1400 combined axilla/groin swabs. Characteristics of swabbed residents are found in Table 2. MDRO colonization was identified in 680 residents. Median MDRO carriage prevalence among NHs was 50% (range 24%70%), presented in Table 3. Median MRSA colonization prevalence was 36% (range: 20%-54%), median ESBL colonization was 16% (range: 2%34%), median VRE colonization was 5% (range: 0%-30%), and median CRE was 0% (range: 0%-8%). All CRE carriers were colonized with *Klebsiella pneumoniae*.

Colonization Iceberg

History of MDRO was found in the medical record for 13% of residents (n 180), including MRSA for 8% of residents (n 116), ESBL for 6% (n 81), VRE for 2% (n 22), and CRE for 0%. We identified previously unknown MDRO carriage in 627 residents, the iceberg population. Overall, unknown MDRO colonization represented nearly half of the total NH population (median across NHs 45%, range: 24%67%). The majority of the unknown MDRO iceberg was found in residents lacking history of any MDRO (n 552) at the NH, including transfer records (Table 3, Figure 1). The remainder of the unknown MDRO iceberg was found in residents with a history of 1 MDRO, but a second previously unknown MDRO was detected upon swabbing (n ¼ 75).

Multivariable Models of Colonization

Multivariable models identified resident and facility characteristics associated with MDRO carriage found in Table 4. Resident factors associated with overall MDRO colonization included urinary catheters [odds ratio (OR) 2.3, confidence interval (CI) 1.4, 4.0, P .002], bed bound status (OR 2.0, CI 1.4, 3.0, P < .001), known history of MRSA (OR 2.0, CI 1.1, 3.5, P ¼ .02), and gastrointestinal devices (OR 1.8, CI 1.1, 3.0, P .03). Facility characteristics associated with overall MDRO colonization included average activities of daily living index (OR 6.7, CI 1.0, 3.99, P .04), proportion of Medicaid patients (OR 1.2, CI 1.0, 1.4, P < .03), and larger number of beds (OR 0.9, CI 0.9, 1.0, P .04). Models for individual MDROs are presented in Table 4. MDRO colonization was similar in post-acute compared with long-stay residents as presented in Supplementary Table 1.

Environmental Contamination

A total of 420 objects from 84 resident rooms were swabbed (Table 5). Resident rooms included those for 28 ambulatory short-stay residents, 28 ambulatory residents with ADRD, and 28 bedbound residents. Environmental contamination with any MDRO was found on 37% of high-touch objects in resident rooms (n 157, range: 7%73%). MDRO was found on 55% of bedside tables/bedrails, 38% of bathrooms, and 33% of room exit door knobs. Overall, 74% of resident rooms were contaminated by an MDRO on at least 1 high-touch object. By MDRO pathogen, 55% of resident rooms were contaminated with MRSA, 38% with VRE, 11% with ESBL, and 1% with CRE. Environmental results by resident status are presented in Table 5.

A total of 140 objects from 28 common rooms were swabbed (Table 5). MDRO colonization was highest on the hallway hand rail (61%), the nursing station counter or cart (57%), and the common room table (54%). Overall, 93% of common areas were contaminated by any MDRO. By MDRO pathogen, 89% of common areas were contaminated with MRSA, 61% with VRE, 7% with ESBL, and 0% with CRE. CRE was only identified in resident bathrooms. Data on contamination of individual objects are presented in Table 5. Data comparing environmental contamination between CMS 1to 3-star and CMS 4and 5-star rated facilities are presented in Supplementary Table 2.

Discussion

In this systematic assessment of environmental contamination and resident MDRO colonization in 28 NHs across Southern California, we found that half of residents harbored an MDRO. Of concern, nearly 90% of MDRO-colonized residents were unknown to the NH. This iceberg of unknown MDRO carriers produces the highest risk of transmission because no targeted infection prevention measures are applied during their stay or upon transfer to an acute care hospital setting.

It should be noted that the iceberg of unrecognized MDRO carriers is the product of multiple factors, including a preponderance of unknown carriage, poor communication from transferring hospitals about known MDRO status, poor retention of asymptomatic MDRO status if communicated, transmission of MDRO within the NH, and unmasking of MDROs following antibiotic treatment. The similar MDRO prevalence among short- and long-stay residents is likely due to the fact that these residents shared staff and common spaces, including dining areas, activity rooms, showers, and other areas (Supplementary Table 1).

The pervasiveness of MDROs highlights the urgent need for practical and effective infection prevention strategies for NHs.6 Targeted strategies for controlling spread of MDROs depend largely on screening and contact precautions for known MDRO patients, both of which are infrequently used in NHs.[6,7] Moreover, our data point to an extensive unknown submerged portion of an “iceberg” of unknown MDRO carriage. The “iceberg” of unknown MDRO carriage could be identified by expanded surveillance in the NH setting. However, given the extremely high burden of disease across multiple MDRO categories and high expense of testing, we would

favor rapid implementation of universal strategies that do not depend on screening tests and would result in a more broad-based benefit to all patients, like high-fidelity hand hygiene, environmental cleaning, chlorhexidine bathing, and nasal decolonization.[4] Furthermore, imperfect adherence to these measures when employed suggests that simultaneous multimodal strategies are needed to prevent transmission and reduce carriage. In fact, these baseline results are from a cluster-randomized trial (https://clinicaltrials.gov/ct2/show/NCT03118232) to evaluate whether a quality assurance and performance improvement initiative focused on universal chlorhexidine bathing and nasal decolonization can reduce MDROs, infections, and hospitalizations.

Results from this study are immediately applicable to infection prevention programs. NH residence is a known risk factor for MDRO carriage[11,12] and acquisition,[3,4,11,13] but here we quantify the high absolute risk of carriage across a large number of NHs. With an approximately 50% risk of MDRO carriage, hospitals receiving NH residents should consider screening and possibly pre-emptive contact precautions while screens are pending to prevent MDRO transmission.[3,4,11,16,17,19-22,25,26]

Table 2
Characteristics of Nursing Home Residents Who Were Swabbed (N = 1400)

Variable	n (%)
Female	889 (64)
Age, y	
<65	207 (15)
65-74	279 (20)
75-84	371 (27)
≥85	543 (39)
Length of stay, d	
<15	178 (13)
15-30	122 (9)
31-100	217 (16)
101-364	537 (38)
≥365	346 (25)
MDRO history by chart review	
Any MDRO	180 (13)
MRSA	116 (8)
VRE	22 (2)
ESBL	81 (6)
CRE	0 (0)
Diabetes	447 (32)
Incontinence status	
Stool	881 (63)
Urine	848 (61)
Bed bound	310 (22)
Devices	250 (18)
GI device*	145 (10)
Urinary catheter	89 (6)
Central venous catheter	34 (2)
Wounds	162 (12)

*Gastrointestinal device: nasogastric tubes, oral-gastric tubes, oral-jejunal tubes, percutaneous gastric tubes.

Table 3
Point Prevalence of MDRO Carriage at Participating Nursing Homes

Nursing Home	Number of Residents Swabbed	Chart History of Any MDRO, n (%)	MDRO Carriage, n (%)	MRSA Carriage, n (%)			VRE Carriage, n (%)	ESBL Carriage, n (%)	CRE Carriage, n (%)	Newly Detected MDRO, n (%)	Newly Detected MDRO Without Any Prior MDRO History, n (%)	Newly Detected MDRO With Prior MDRO History, n (%)
				Any	Nares	Skin						
1	50	7 (14)	35 (70)	23 (46)	19 (38)	14 (28)	10 (20)	13 (26)	0 (0)	34 (68)	29 (67)	5 (71)
2	50	6 (12)	31 (62)	23 (46)	19 (38)	15 (30)	2 (4)	12 (24)	3 (6)	30 (60)	28 (64)	2 (33)
3	50	8 (16)	30 (60)	18 (36)	14 (28)	11 (22)	3 (6)	17 (34)	1 (2)	30 (60)	26 (62)	4 (50)
4	50	12 (24)	30 (60)	24 (48)	20 (40)	21 (42)	7 (14)	15 (30)	4 (8)	29 (58)	18 (47)	11 (92)
5	50	10 (20)	30 (60)	24 (48)	21 (42)	17 (34)	5 (10)	9 (18)	0 (0)	27 (54)	22 (55)	5 (50)
6	50	1 (2)	30 (60)	27 (54)	18 (36)	23 (46)	3 (6)	7 (14)	0 (0)	30 (60)	29 (59)	1 (100)
7	50	6 (12)	30 (60)	22 (44)	16 (32)	16 (32)	7 (14)	9 (18)	0 (0)	29 (58)	26 (59)	3 (50)
8	50	5 (10)	29 (58)	20 (40)	18 (36)	13 (26)	2 (4)	11 (22)	1 (2)	27 (54)	25 (56)	2 (40)
9	50	0 (0)	29 (58)	27 (54)	23 (47)	20 (40)	0 (0)	4 (8)	0 (0)	29 (58)	29 (58)	0
10	50	6 (12)	29 (58)	23 (46)	20 (40)	13 (26)	5 (10)	10 (20)	0 (0)	27 (54)	23 (52)	4 (67)
11	50	5 (10)	27 (54)	18 (36)	13 (26)	15 (30)	15 (30)	5 (10)	0 (0)	26 (52)	23 (51)	3 (60)
12	50	8 (16)	26 (52)	16 (32)	13 (26)	11 (22)	11 (22)	10 (20)	1 (2)	24 (48)	20 (48)	4 (50)
13	50	8 (16)	25 (50)	22 (44)	20 (40)	14 (28)	1 (2)	6 (12)	1 (2)	21 (42)	18 (43)	3 (38)
14	50	2 (4)	25 (50)	25 (50)	15 (30)	16 (32)	0 (0)	2 (4)	0 (0)	25 (50)	24 (50)	1 (50)
15	50	5 (10)	25 (50)	21 (42)	17 (34)	18 (36)	4 (8)	8 (16)	0 (0)	24 (48)	22 (49)	2 (40)
16	50	17 (34)	24 (48)	15 (30)	14 (28)	7 (14)	1 (2)	16 (32)	0 (0)	18 (36)	14 (42)	4 (24)
17	50	11 (22)	23 (46)	18 (36)	16 (32)	5 (10)	4 (8)	8 (16)	0 (0)	19 (38)	15 (38)	4 (36)
18	50	12 (24)	23 (46)	21 (42)	16 (32)	15 (30)	1 (2)	6 (12)	0 (0)	18 (36)	15 (39)	3 (25)
19	50	8 (16)	21 (42)	12 (24)	8 (17)	10 (20)	7 (14)	5 (10)	0 (0)	17 (34)	16 (38)	1 (13)
20	50	1 (2)	21 (42)	15 (30)	12 (24)	7 (14)	0 (0)	11 (22)	1 (2)	21 (42)	20 (41)	1 (100)
21	50	8 (16)	19 (38)	15 (30)	9 (18)	11 (22)	1 (2)	3 (6)	0 (0)	17 (34)	14 (33)	3 (38)
22	50	11 (22)	19 (38)	14 (28)	12 (24)	8 (16)	1 (2)	8 (16)	0 (0)	13 (26)	13 (33)	0 (0)
23	50	5 (10)	19 (38)	15 (30)	15 (30)	8 (16)	0 (0)	8 (16)	0 (0)	16 (32)	16 (36)	0 (0)
24	50	10 (20)	18 (36)	15 (30)	12 (24)	7 (14)	0 (0)	8 (16)	0 (0)	17 (34)	12 (30)	5 (50)
25	50	2 (4)	17 (34)	10 (20)	7 (14)	6 (12)	4 (8)	6 (12)	0 (0)	16 (32)	15 (31)	1 (50)
26	50	4 (8)	17 (34)	11 (22)	10 (20)	3 (6)	3 (6)	4 (8)	0 (0)	16 (32)	14 (30)	2 (50)
27	50	2 (4)	16 (32)	13 (26)	11 (22)	8 (16)	2 (4)	6 (12)	1 (2)	15 (30)	14 (29)	1 (50)
28	50	0 (0)	12 (24)	11 (22)	4 (8)	9 (18)	0 (0)	1 (2)	0 (0)	12 (24)	12 (24)	0
Total residents	1400	180 (13)	680 (49)	518 (37)	412 (29)	341 (24)	99 (7)	228 (16)	13 (1)	627 (45)	552 (45)*	75 (42)†
Facility mean % (SD)		13 (0.08)	49 (0.11)	37 (0.10)	29 (0.09)	24 (0.10)	7 (0.08)	16 (0.08)	1 (0.02)	45 (0.12)	45 (0.12)	47 (0.25)
Facility median % (range)		12 (0-34)	50 (24-70)	36 (20-54)	30 (8-47)	24 (6-46)	5 (0-30)	16 (2-34)	0 (0-8)	45 (24-68)	45 (24-67)	50 (0-100)

*Total MDRO detected among residents without a documented history of MDRO (n = 1220).
†Total newly detected MDRO among residents with a documented history of MDRO (n = 180).

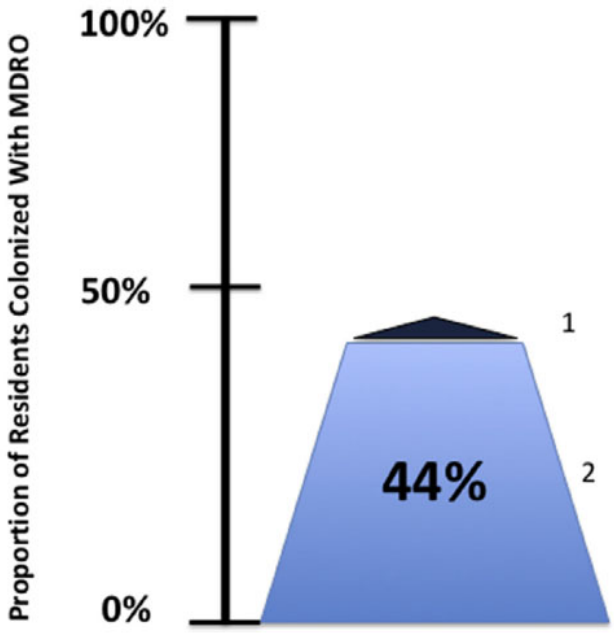

Fig. 1. The iceberg of MDRO colonization in skilled nursing facilities. (1) Nearly half (48%) of nursing home residents are colonized with MDRO. The top "exposed" portion of the iceberg represents the (4%) of patients for whom point prevalence survey confirmed previously known colonization status (n = 53 residents). (2) Most of the MDRO colonization is unknown to the facility, with 45% of residents representing the unknown submerged iceberg population of previously unknown MDRO colonization.
Of the NH population, 39% (n ¼ 552 residents) had no history of MDRO, but point prevalence survey identified MDRO Carriage. In addition, 5% of the NH population (n ¼ 75 residents) had a history of an MDRO, but point prevalence survey identified an additional MDRO unknown to the facility.

Our environmental surveillance found that MDRO contamination was higher in common areas than patient rooms. Although MDRO contamination was seen in three-quarters of resident rooms, almost all of the common rooms (93%) had evidence of MDRO contamination. Perhaps most strikingly, the hallway handrail (61%) and nursing station (57%) were both more commonly contaminated than the bedside table/bedrail in resident rooms (55%). One observation from the environmental surveillance data was that rooms of patients with ADRD appeared to have higher room contamination with ESBL and CRE than other rooms. In addition, patient room contamination appeared to be more common in 1- to 3-star facilities compared with 4- and 5-star facilities (Supplementary Table 2). These observations are hypothesis generating and should be explored in future studies with a larger selection of facilities and multiple rounds of repeat environmental testing. Despite the limitations, our environmental surveillance data suggest that high-fidelity environmental cleaning of common areas must be emphasized in addition to cleaning of resident rooms. The overall observation from these data is that more resources should be directed toward cleaning of the entire environment.

Our study was limited in geography to Southern California NHs. Thus, the reported burden of MDROs reflects regional MDRO prevalence. This is especially important for CRE, which was first noted in Southern California in 2009. We note, however, that our other MDRO findings are similar to previous smaller studies conducted in California, Illinois, Maryland, Massachusetts, Michigan, and Washington.[3,11-14,16,17,20,21,25,27,28] In addition, our efforts to determine a history of MDRO were limited to NH medical records and transfer records. It is possible that comprehensive review of a patient's full multifacility medical record would have revealed a prior MDRO culture. We also did not collect data on number or type of previous hospitalizations or previous exposures to other health care facilities. Nevertheless, our results represent known status at the NH, and are thus reflective of information that would impact care in that setting. Another limitation is that our sampling was limited to nares and skin. Collection of concomitant throat or rectal swabs would have increased MDRO detection. Although we initially included a broth enrichment step, this was rapidly discontinued due to the high growth of MDROs without it. Thus, our measured prevalence of MRSA, VRE, ESBL, and CRE colonization are likely underestimates.

Table 4
Multivariable Regression for Factors Associated with MDRO Colonization in NH Residents based on Nares and Skin Swabs

Variable*	OR (95% CI)	*P* Value
Any MDRO†		
Bed bound	2.0 (1.4, 3.0)	<.001
Urinary catheter	2.5 (1.3, 4.9)	.007
GI device	1.8 (1.1, 3.0)	.03
History of MRSA	2.0 (1.1, 3.5)	.02
NH mean ADL Index	6.7 (1.0, 39.9)	.04
NH % Medicaid‡	1.2 (1.0, 1.4)	.03
NH total beds	0.9 (0.9, 1.0)	.04
Any MRSA§		
Bed bound	1.7 (1.2, 2.2)	<.001
Urinary catheter	1.8 (1.1, 2.8)	.01
Diabetes	1.4 (1.1, 1.8)	.01
Age per decade	1.1 (1.0, 1.2)	.03
History of MRSA	1.6 (1.0, 2.4)	.03
Any VRE‖		
Wounds	2.2 (1.3, 3.8)	.01
Central venous catheter	3.0 (1.1, 8.3)	.03
Urinary catheter	2.1 (1.1, 4.1)	.03
NH annual admissions	1.1 (1.0, 1.1)	.01
Any ESBL**		
Incontinence of stool	1.8 (1.4, 2.3)	<.001
GI device	1.7 (1.3, 2.4)	<.001
Urinary catheter	1.5 (1.0, 2.3)	.05
History of ESBL	4.8 (3.3, 6.9)	<.001
Any CRE††		
Central venous catheter	25.4 (3.3, 197.4)	.002
GI device	42.7 (8.7, 208.4)	<.001

*Models accounted for clustering at the resident and NH level. Variables were entered into the model unless there was evidence of collinearity.
†Only significantly associated variables are shown. Model also adjusts for resident characteristics including gender, age, length of stay, diabetes status, history of VRE, presence of wounds, and presence of a central venous catheter. Model also adjusts for NH characteristics including mean Elixhauser comorbidity score, occupancy ratio, CMS 5-star quality rating, mean ADL index, and proportion of residents whose primary insurance is Medicare (% Medicare).
‡% Medicaid refers to the proportion of residents whose primary insurance is Medicaid.
§Only significantly associated variables are shown. Model also adjusts for gender, length of stay, history of MRSA, history of ESBL, presence of a GI device, presence of wounds, facility mean ADL index, facility percentage Medicare-insured, and facility percentage Medicaid-insured.
‖Only significantly associated variables are shown. Model also adjusts for diabetes status, history of VRE, history of MRSA, and history of ESBL.
**Only significantly associated variables are shown. Model also adjusts for gender, age, length of stay, history of MRSA, presence of wounds, presence of a central venous catheter, NH facility total beds, facility percentage Medicare-insured, and facility percentage Medicaid-insured.
††Only significantly associated variables are shown. Model also adjusts for age and history of VRE.

Table 5
Environmental MDRO Contamination From High-Touch Objects

	n	Any MDRO, %	MRSA, %	VRE, %	ESBL, %	CRE, %
Resident room: high-touch objects						
Bedside table and bedrail	84	55	31	29	5	0
Call button, TV remote, phone	84	35	23	15	1	0
Door knobs	84	33	24	12	1	0
Light switch	84	26	18	8	1	0
Bathroom rail, sink, flush handle	84	38	23	20	5	1
Any object	420	37	24	17	3	0.2
Common room: high-touch objects						
Nursing station counter or cart	28	57	43	32	0	0
Table	28	54	39	29	4	0
Chair	28	46	29	18	0	0
Hand rail (hallway)	28	61	32	32	4	0
Drinking fountain or drinking station	28	32	25	11	0	0
Any object	140	50	34	24	1	0
Contamination by room type						
Common room	28	93	89	61	7	0
Resident room	84	74	55	38	11	1
Ambulatory short stay	28	79	46	46	7	0
Ambulatory ADRD	28	71	61	36	18	4
Total care	28	71	57	32	7	0
Any room	112	79	63	44	10	0.9

Conclusions and Implications

MDRO colonization prevalence within NHs is exceedingly high, greater than other clinical care settings by several-fold.11,29,30 The large unknown submerged portion of iceberg of MDRO carriage within this population is a call to action during a time when NH infection prevention activities are newly regulated by CMS. The fact that a majority of residents and rooms are affected by MDRO carriage and contamination lends greater support to universal strategies such as routine decolonization to help protect the vulnerable population of NH residents. To that end, this study represents baseline data from the ongoing Project Protect cluster-randomized trial, which will provide insight into the effectiveness of decolonization for reducing MDRO colonization, infection, and hospitalization.

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Supplementary Table 1
MDRO Carriage in Post-Acute and Long-Stay Residents

	n	Any MDRO, %	MRSA, %	VRE, %	ESBL, %	CRE, %
All residents						
Nares	1397	29	29	—	—	—
Axilla/groin	1400	39	24	7	16	1
All body sites	1400	49	37	7	16	1
Post-acute						
Nares	306	26	26	—	—	—
Axilla/groin	306	41	25	15	15	1
All body sites	306	48	34	15	15	1
Long-stay						
Nares	1091	30	30	—	—	—
Axilla/groin	1094	38	24	5	17	1
All body sites	1094	49	38	5	17	1

CRE, carbapenem-resistant Enterobacteriaceae; ESBL, extended-spectrum betalactamase producing organism; MDRO, multidrug-resistant organism; MRSA, methicillin-resistant Staphylococcus aureus; VRE, vancomycin-resistant Enterococcus spp.

Supplementary Table 2
Nursing Home MDRO Body Carriage and Environmental Contamination by CMS Star Rating

		MDRO Body Swab Carriage Median (Range)					MDRO Environmental Contamination: % Objects Contaminated Median (Range)									
							Resident Rooms					Common Areas				
CMS Star Rating	Nursing Homes, n	Any MDRO	Any MRSA	Any VRE	Any ESBL	Any CRE	Any MDRO	Any MRSA	Any VRE	Any ESBL	Any CRE	Any MDRO	Any MRSA	Any VRE	Any ESBL	Any CRE
1- to 3-star	13	54 (36-70)	42 (30-54)	4 (0-30)	20 (4-32)	0 (0-8)	47 (7-73)	20 (0-53)	27 (0-60)	0 (0-7)	0 (0-7)	60 (0-100)	20 (0-60)	20 (0-60)	0 (0-20)	0 (0-0)
4- or 5-star	15	42 (24-60)	30 (20-54)	6 (0-14)	12 (2-34)	0 (0-2)	27 (7-73)	20 (0-53)	7 (0-47)	0 (0-20)	0 (0-0)	60 (0-100)	20 (0-80)	20 (0-100)	0 (0-0)	0 (0-0)

CRE, carbapenem-resistant Enterobacteriaceae; CMS, Centers for Medicare & Medicaid Services; ESBL, extended-spectrum beta-lactamase producing organism; MDRO, multidrug-resistant organism; MRSA, methicillin-resistant *Staphylococcus aureus*; VRE, vancomycin-resistant *Enterococcus* spp.