

ORIGINAL ARTICLE

Multidrug-Resistant Organism Infections in US Nursing Homes: A National Study of Prevalence, Onset, and Transmission across Care Settings, October 1, 2010–December 31, 2011

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OBJECTIVE. To understand the prevalence of multidrug-resistant organism (MDRO) infections among nursing home (NH) residents and the potential for their spread between NHs and acute care hospitals (ACHs).

METHODS. Descriptive analyses of MDRO infections among NH residents using all NH residents in the Long-Term Care Minimum Data Set (MDS) 3.0 between October 1, 2010 and December 31, 2011.

RESULTS. Analysis of MDS data revealed a very high volume of bidirectional patient flow between NHs and ACHs, indicating the need to study MDRO infections in NHs as well as in hospitals. A total of 4.24% of NH residents had an active MDRO diagnosis on at least 1 MDS assessment during the study period. This rate significantly varied by sex, age, urban/rural status, and state. Approximately 2% of NH discharges to ACHs involved a resident with an active diagnosis of infection due to MDROs. Conversely, 1.8% of NH admissions from an ACH involved a patient with an active diagnosis of infection due to MDROs. Among residents who acquired an MDRO infection during the study period, 57% became positive in the NH, 41% in the ACH, and 2% in other settings (eg, at a private home or apartment).

CONCLUSION. Even though NHs are the most likely setting where residents would acquire MDROs after admission to an NH (accounting for 57% of cases), a significant fraction of NH residents acquire MDRO infection at ACHs (41%). Thus, effective MDRO infection control for NH residents requires simultaneous, cooperative interventions among NHs and ACHs in the same community.

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Healthcare-associated infections (HAIs) are infections that patients acquire during the course of receiving healthcare treatment for other conditions. The Centers for Disease Control and Prevention estimated that the 1.74 million HAIs reported in 2007 cost US hospitals between \$28.4 and \$33.8 billion.¹ In response, the US government instituted policy changes to reduce the incidence of HAIs. Under the Affordable Care Act, states were required to start reporting their rates of HAIs in 2012.² Beginning in 2015, hospitals in the quartile with the highest number of HAIs will have their Medicare payments reduced by 1%.³

Two-thirds of all HAIs come from just 6 multidrug-resistant organisms (MDROs).⁴ These include *Enterococcus* species (vancomycin-resistant enterococci [VRE]), *Staphylococcus aureus* (methicillin-resistant *S. aureus* [MRSA], vancomycin-intermediate *S. aureus* [VISA], or vancomycin-resistant *S. aureus* [VRSA]), *Klebsiella pneumoniae*, *Acinetobacter baumannii*, *Pseudomonas aeruginosa*, and *Enterobacter* species

(extended-spectrum β -lactamase-producing gram-negative bacilli [ESBL] and fluoroquinolone-resistant *P. aeruginosa*).

The prevalence of MDROs in medical centers has increased steadily.⁵ Older patients are among the main reservoirs of MDROs in the hospital. In a study conducted in a 620-bed tertiary care healthcare facility in Boston, admission prevalence per 1,000 for MRSA, VRE, and multidrug-resistant gram-negative bacteria (MDRGN) was consistently higher among the elderly population than among other age groups. Furthermore, admission prevalence among the elderly population increased significantly over time for VRE (from 0.89 cases per 1,000 admissions in 1998 to 3.62 cases per 1,000 admissions in 2009) and MDRGN (1.41 cases per 1,000 admissions in 1998 to 11.33 cases per 1,000 admissions in 2009). The admission prevalence of MRSA increased until 2003 and then decreased (6.6 cases per 1,000 admissions in 1998, 24.8 in 2003, and 16.3 in 2009).⁶

It is not surprising that MDROs are also a serious concern

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TABLE 1. Distribution of Nursing Home Residents by Demographic Characteristic and Prevalence of Multidrug-Resistant Organisms (MDROs) among Residents in Each Category

Demographic characteristic	Overall nursing home resident population	Residents who ever received a diagnosis involving MDRO
Total	100 (4,165,596)	4.24 (176,806)
Age, years		
Mean \pm SD	77.43 \pm 13.36	74.81 \pm 14.22
≤ 17	0.17 (7,153)	3.54 (253)
18–29	0.35 (14,617)	7.12 (1,041)
30–39	0.69 (28,549)	7.52 (2,148)
40–49	2.28 (95,167)	6.76 (6,431)
50–54	2.78 (115,682)	5.90 (6,821)
55–60	4.13 (171,955)	5.46 (9,388)
60–64	5.73 (238,778)	5.16 (12,328)
65–69	7.95 (331,122)	4.94 (16,354)
70–74	9.92 (413,202)	4.56 (18,839)
75–79	13.36 (556,487)	4.25 (23,654)
80–84	17.88 (744,769)	3.99 (29,681)
85–89	18.63 (775,809)	3.71 (28,759)
90–94	11.56 (481,576)	3.28 (15,801)
95–99	3.90 (162,413)	2.89 (4,701)
≥ 100	0.67 (27,950)	2.11 (591)
Sex		
Male	35.93 (1,496,203)	5.24 (78,413)
Female	64.07 (2,668,462)	3.69 (98,355)
Race/ethnicity		
White	80.04 (3,328,527)	4.25 (141,353)
Black	10.92 (454,213)	4.22 (19,148)
Hispanic	4.34 (180,630)	4.16 (7,509)
Asian	1.50 (62,364)	3.70 (2,309)
American Indian or Alaska Native	0.39 (16,322)	5.18 (845)
Native Hawaiian/ Pacific Islander	0.30 (12,291)	4.21 (517)
Marital status		
Never married	14.25 (576,833)	4.87 (28,074)
Married	30.54 (1,236,230)	4.47 (55,302)
Widowed	43.04 (1,741,940)	3.69 (64,364)
Separated	1.33 (53,955)	4.87 (2,626)
Divorced	10.84 (438,704)	4.82 (21,148)
Urban/rural		
Urban	81.15 (3,380,273)	4.38 (148,133)
Rural	18.85 (785,323)	3.65 (28,673)
Overall	100 (4,165,596)	4.24 (176,806)

NOTE. Data are percentage (no.) of residents, unless otherwise indicated. SD, standard deviation.

in long-term care settings, especially those that serve the frail elderly population.⁷ In a screening performed in a 120-bed skilled nursing facility in the absence of a clinical “outbreak,” 43% of residents were found to be carrying a drug-resistant organism. Once introduced in a long-term care facility (LTCF), MDROs tend to become endemic.⁸ Having stayed in a LTCF is a risk factor for invasive MRSA infection. In a study of patient intake forms at a 980-bed tertiary care hospital

between 1996 and 1997, patients admitted from nursing homes (NHs) were 6.4 times more likely to have MRSA than those who had come to the hospital from other places.⁹ NHs often have a higher prevalence of MRSA colonization than hospitals and ICUs.^{10,11} More than half the residents of LTCFs are thought to harbor MDRGN.¹²⁻¹⁴

It is important to distinguish between colonization and clinical infection. Colonization is an asymptomatic presence

TABLE 2. Distribution of Nursing Home Residents by State and Prevalence of Multidrug-Resistant Organisms (MDROs) among Residents in Each State

State	Percentage (no.) of residents	
	Overall nursing home population	Residents who ever received a diagnosis involving MDRO
AK	0.03 (1,436)	5.92 (85)
AL	1.53 (63,752)	1.87 (1,192)
AR	0.96 (40,194)	3.13 (1,259)
AZ	1.49 (62,224)	4.49 (2,794)
CA	8.66 (360,918)	4.05 (14,610)
CO	1.28 (53,262)	2.41 (1,285)
CT	1.89 (78,671)	5.67 (4,461)
DC	0.16 (6,732)	3.46 (233)
DE	0.31 (13,009)	4.40 (572)
FL	6.65 (276,989)	4.05 (11,231)
GA	2.04 (84,792)	2.86 (2,426)
HI	0.28 (11,511)	2.88 (331)
IA	1.35 (56,202)	3.64 (2,048)
ID	0.38 (15,852)	3.69 (585)
IL	4.97 (207,050)	5.42 (11,231)
IN	2.56 (106,604)	3.20 (3,414)
KS	1.05 (43,914)	3.38 (1,484)
KY	1.54 (64,308)	4.42 (2,840)
LA	1.24 (51,722)	2.49 (1,286)
MA	3.24 (134,782)	6.15 (8,289)
MD	2.01 (83,589)	5.43 (4,540)
ME	0.54 (22,527)	3.25 (733)
MI	3.25 (135,188)	3.69 (4,984)
MN	2.09 (86,946)	3.86 (3,354)
MO	2.31 (96,317)	3.31 (3,190)
MS	0.84 (34,932)	2.42 (847)
MT	0.31 (12,814)	2.95 (378)
NC	2.74 (114,340)	3.34 (3,822)
ND	0.30 (12,396)	5.17 (641)
NE	0.79 (32,957)	3.91 (1,290)
NH	0.47 (19,376)	5.85 (1,134)
NJ	3.72 (155,099)	4.86 (7,534)
NM	0.44 (18,274)	2.99 (546)
NV	0.51 (21,103)	6.33 (1,335)
NY	6.93 (288,786)	4.41 (12,749)
OH	5.75 (239,316)	4.74 (11,351)
OK	1.11 (46,137)	2.19 (1,009)
OR	0.87 (36,145)	2.77 (1,003)
PA	5.75 (239,505)	5.68 (13,612)
RI	0.55 (22,713)	11.42 (2,593)
SC	1.22 (50,877)	2.54 (1,292)
SD	0.32 (13,323)	3.73 (497)
TN	2.13 (88,575)	3.55 (3,147)
TX	5.79 (241,067)	3.21 (7,736)
UT	0.60 (24,825)	2.40 (595)
VA	2.26 (93,947)	6.34 (5,958)
VT	0.21 (8,823)	6.28 (554)
WA	1.7 (70,848)	4.52 (3,204)
WI	2.13 (88,687)	3.75 (3,324)
WV	0.63 (26,431)	7.80 (2,062)
WY	0.14 (5,809)	2.34 (136)
Overall	100 (4,165,596)	4.24 (176,806)

TABLE 3. Distribution of Nursing Home Residents by US Census Bureau Region and Division and Prevalence of Multidrug-Resistant Organisms (MDROs) among Residents in Each Region and Division

Geographic area	Percentage (no.) of residents	
	Overall nursing home population	Residents who ever received a diagnosis involving MDRO
Census region		
Midwest	26.86 (1,118,900)	4.18 (46,808)
Northeast	23.29 (970,282)	5.32 (51,659)
South	33.16 (1,381,393)	3.72 (51,452)
West	16.68 (695,021)	3.87 (26,887)
Census division		
Midwest		
West North Central	8.21 (342,055)	3.66 (12,504)
East North Central	18.65 (776,845)	4.42 (34,304)
Northeast		
Middle Atlantic	16.41 (683,390)	4.96 (33,895)
New England	6.89 (286,892)	6.19 (17,764)
South		
West South Central	9.10 (379,120)	2.98 (11,290)
East South Central	6.04 (251,567)	3.19 (8,026)
South Atlantic	18.02 (750,706)	4.28 (32,136)
West		
Mountain	5.14 (214,163)	3.57 (7,654)
Pacific	11.54 (480,858)	4.00 (19,233)
Overall	100 (4,165,596)	4.24 (176,806)

of pathogenic bacteria in culture specimens. Clinical guidelines for managing infections in LTCFs suggest that, in most cases, colonization with no clinical symptoms of infection should not be treated, to minimize the risk of creating MDROs. Clinical infections (ie, those that exhibit symptoms) should be treated in most cases.^{15,16} Furthermore, MDRO-colonized LTCF residents can eventually exhibit symptoms that require treatment according to guidelines¹⁷ and can become the source of transmission to other healthcare settings.¹⁸⁻²⁸

The increasing prevalence of clinical MDRO infections is associated with increased lengths of stay, costs, and mortality.²⁹ The demand for places in LTCFs will grow substantially in the next 2 decades as the large population cohort born before 1964 ages. It is estimated that people using paid LTCFs will double to 27 million by 2050.³⁰ Thus, the cost and quality of care, the risk of HAIs, and the prevalence of MDROs in LTCFs are important issues for society.

There are several gaps in the literature. First, the literature does not examine the patterns of transmission to and from LTCFs and ACHs. Second, few earlier studies reported on the racial or geographic disparities in MDRO prevalence. Third, we were not able to find any study that described the transmission of the infection and its pattern of transmission across settings.

METHODS

This study uses the Centers for Medicare and Medicaid Services (CMS) Long Term Care Minimum Data Set (MDS).³¹ MDS is a standardized, primary screening and assessment tool that measures physical, clinical, psychological, and psychosocial functional status and life care wishes of all residents (regardless of payer) of Medicare- or Medicaid-certified NHs. MDS data include a resident-level active MDRO infection indicator measured at admission and periodically thereafter (at least quarterly), the type of setting from which the resident is admitted, and the type of setting to which the resident is discharged. These settings include community (private home or apartment, board or care, assisted living, and group home), another NH or swing bed facility, ACH, psychiatric hospital, inpatient rehabilitation facility, intellectual disability or developmental disability facility, hospice, and long-term care hospital. Although it would be desirable to study the rates of both asymptomatic and symptomatic infections, the MDS captures only clinically symptomatic infections. Although it would be useful to include all types of LTCFs in the study, MDS data are collected only in Medicare- and Medicaid-certified NHs.

For this study, we used national MDS data for 15 months from October 1, 2010, through December 31, 2011. During this period, there were 135 days, on average, between MDS assessments, with a median of 51 days. There were approximately 16,000 facilities with at least 1 MDS record. There was at least 1 assessment record for 4,165,596 residents. On average, residents had 4.6 assessments with a median of 4 during this time period.

Our analysis sought to address the following 6 research questions: (1) What is the frequency of NH admissions from ACHs and discharges to ACHs? (2) What percentage of hospital episodes involving adults (more than 65 years old) in the United States in 2011 were either immediately preceded by an NH discharge to the hospital or immediately succeeded by admission to an NH? (3) What is the national overall prevalence of MDRO infections among NH residents, and are there demographic or geographic disparities? (4) How many NH admissions and discharges from hospitals are of individuals who have MDRO infections? (5) How many NH residents acquire MDRO infections after NH admission? (6) How long does it take for NH residents to acquire MDRO infections in NHs?

We used quantitative descriptive analysis to calculate prevalence across a number of strata. We also developed 2 algorithms to identify the possible source setting of the infection and define a unit of observation for analyzing the onset of the infection. The counts and rates reported are for the US population of NH residents during the period October 1, 2010, through December 31, 2011. Because control of MDROs is a major patient safety initiative for NHs and hospitals nationwide, we expect these rates to improve with time. Thus, we are reluctant to imply that they reflect a larger

TABLE 4. Multidrug-Resistant Organism (MDRO) Data by Quarter

Study cohort (sample size = 720,788)	Baseline quarter (average start date: mid-November 2010)	Follow-up quarter 1 (average start date: mid-February 2011)	Follow-up quarter 2 (average start date: mid-May 2011)	Follow-up quarter 3 (average start date: mid-August 2011)
MDRO infection prevalence	1.38	1.34	1.26	1.32
MDRO infection rate (new infections) among residents with no infection reported at baseline	...	0.70	0.80	0.93
Cumulative MDRO infection rate among residents with no infection reported at baseline	...	0.70	1.31	1.92

population of persons who might reside in NHs at other time periods and have accordingly chosen to treat the residents of US NHs during this period as a finite census population. As is appropriate for a finite census, we have not computed variances or tested for the statistical significance of the differences observed between population groups. These rates have not been reported previously and serve as a baseline against which future counts and estimates from other sources can be compared.

RESULTS

Transitions between NHs and ACHs

During the 15-month study period, there were 2,102,128 discharges from NHs to ACHs for 1,279,608 unique NH residents. These discharges represent 45% of all discharges from NHs and 30.7% of all residents who were discharged at least once.

During this period, 90% of all admissions to NHs (4,399,280 admissions) came from ACHs. Approximately 2,914,705 NH residents (62.1% of all residents) were admitted to an NH immediately after discharge from ACHs.

To understand what these results could mean for all hospitals, we extrapolated the study's findings to data from the Agency for Healthcare Research and Quality's (AHRQ's) Healthcare Cost and Utilization Project (HCUP). AHRQ's HCUP reports that there were a total of 13,816,586 discharges of older adults from all hospitals in the United States in 2011. According to our calculations from MDS data for the same period, at least 2,965,678 of such hospital episodes (21.5%) were either immediately preceded by an NH discharge to the hospital or immediately succeeded by admission to an NH. Such hospital episodes were experienced by 2,046,501 NH residents (69%) who were 65 years of age and older.

These findings show that there is a very high volume of patient flow between NHs and hospitals. This indicates dramatic potential of MDRO transmission across these settings. Thus, MDRO infections in NHs are expected to have strong implications for MDRO infections in hospitals.

Prevalence of MDROs

As displayed in Table 1, 4.24% of NH residents had a MDRO on at least 1 assessment during their NH stay. Male residents had a higher rate of infection than female residents (5.24% and 3.69%, respectively). American Indian and Alaska Natives had the highest rate of infection at 5.18%, and Asians had the lowest rate (3.70%). Infection rate by marital status varied by just over 1%, with the lowest rate among widowed residents (3.69%) and the highest rate among never married and separated residents (both at 4.87%). Residents in an urban setting had a rate of 4.28%, and those in a rural setting had a rate of 3.65%.

The rate of infection in NHs varied by age group, with the lowest prevalence among the oldest residents (those over 100 years old) at 2.11% and the highest among those 30–39 years old (7.52%) and 18–29 years old (7.12%). The age bands that represented the largest proportions of the population were 75–79 years old (13.36%), 80–84 years old (17.88%), 85–89 years old (18.63%), and 90–94 years old (11.56%), and prevalence in these groups was 4.25%, 3.99%, 3.71%, and 3.28%, respectively.

As Table 2 shows, there was a large variation in MDRO prevalence among the states, with nearly 11 percentage points separating the state with the lowest prevalence (Alabama, at 1.87%) and the state with the highest prevalence state (Rhode Island, at 11.42%).

In addition to large variations between states, there were also regional variations, as exhibited in Table 3. The Northeast was the only region with MDRO prevalence above the national rate (5.32% vs 4.24%). Of the remaining 3 regions, the South had the lowest prevalence at 3.72%, the West had a prevalence of 3.87%, and the Midwest, at 4.18%, had a prevalence around the national average.

Looking at more granular data reveals divisions that are driving the Regional results. The South's low prevalence was fairly uniform across its 3 divisions (ie, West South Central, East South Central, and South Atlantic). The West South Central Division within the South had the lowest prevalence at 2.98%, with East South Central immediately behind at 3.19%. The South Atlantic was at 4.28%, close to the national

rate. However, at the other end of the spectrum, the division with highest prevalence (New England, at 6.19%) was the main reason that the Northeast Region had the highest prevalence among the regions. Within New England, all but 1 of the 6 States had very high prevalences.

MDRO Acquisition Rates

The acquisition of MDROs in NHs can be measured by identifying residents who were MDRO negative at their first assessment after admission to the NH and MDRO positive at a subsequent assessment, or those who were MDRO positive at their first assessment after admission but for whom the time between admission and first assessment is longer than 7 days. We estimated the frequency of MDRO acquisition in ACHs by identifying residents who were already MDRO positive on their first assessment after readmission to the NH from the hospital and for whom the time between the readmission date and the date of the first assessment is shorter than or equal to 7 days. If residents were already MDRO positive at their first assessment, which was usually administered several days after the readmission to the NH, it is difficult to identify whether the MDRO onset occurred after returning to the NH or before returning. We therefore required a "clean period" of 7 days. If residents stayed in the NH more than 7 days and were MDRO positive at their first assessment in the NH, then we attributed the acquisition of MDRO to the NH; on the contrary, if their stay in NH before the first assessment was shorter than 7 days and they were MDRO positive at the first assessment, we attributed the acquisition of MDRO to other settings outside the NH. The method of estimating acquisition rates in the NHs is reasonably precise, because residents resided only at the NH during the period they converted from negative to positive. Our estimates of acquisition in the hospital are less precise, because it is possible that the resident acquired infection between the last assessment before transfer to the hospital or after returning to the NH following discharge from the hospital. A more precise estimate of hospital acquisition would require the ability to link NH assessment and hospital admission and discharge records for specific residents, which was not possible in this study. Nevertheless, with this caveat, these estimates provide a useful comparison between NH and ACH acquisition of MDROs by NH residents.

Among the 176,806 residents who had an active MDRO infection in the NH at any time during the study period, 61% (108,065) transitioned from "no infection" (coded as 0) to "infection" (coded as 1). Of those 108,065 residents who had a change in infection status from 0 to 1, we found that 57% had the change occur in the NHs, 41% had the change occur in the ACHs, and 2% had the change occur in other settings. Even though the leading source of infections seems to be NHs, ACHs are not too far behind.

To assess the onset of MDRO infections, a cohort of res-

idents were specified for whom consecutive assessments were available throughout the study period. It is critical to define a period (ie, observation unit for a resident) in which MDRO infection indicator can be specified consistently across residents and over time. Defining an observation unit for outcome variables such as "ever reported to have an MDRO infection" is challenging. There are a variety of reasons for a resident to be assessed at various time points. Additionally, many residents will not be observed during the entire study period, because they may be outside of NHs for 1 or more times. There is no readily available consistent observation unit. Therefore, we created an observation unit from the timing of assessments of all kinds. MDRO infection was included in all assessments. Because each resident is supposed to have at least a quarterly assessment, we defined our unit of observation to be a quarter per resident. For most residents, the analysis quarters were determined by the dates of consecutive quarterly assessments. For others, 1 or more analysis quarters were defined by a combination of various assessments at different times, such as 14-day, 30-day, 60-day, quarterly, admission, or discharge assessments. These residents have multiple assessments contributing to the quarterly MDRO infection indicator. This method is more accurate in capturing residents with an MDRO infection in a quarter than a method that only looks at MDRO status at a single point in time.

An analysis quarter is defined to be at least 77 days and at most 107 days. This is consistent with the MDS manual, which indicates that quarterly assessments can be done up to 2 weeks sooner. One hundred and seven days is approximately 2 weeks longer than a calendar quarter. Two alternative definitions (up to zero days longer and up to 1 week longer) were tested, but the results did not change significantly.

Even though CMS data covers all resident assessments done in the 5 calendar quarters, very few residents will have assessments covering the full 5 quarters. These are the ones who have been residents in each of the 5 quarters, had at least a total of 6 assessments in the study period (2 dates defines a quarter), and 2 of these assessments occurred at the very beginning of the first quarter and at the very end of the fifth quarter. The majority will have at most 4 quarters of assessments. So, the longitudinal data we created include 4 quarters, which allows for 1 baseline quarter and 3 follow-up quarters (Table 4). Of the 4,165,596 residents having at least 1 assessment in the study period, only 1,009,170 (24.2%) had the minimum necessary number of days between their first and last assessments (308 days). Of the 1,009,170 residents, 730,899 (72.4%) had 5 assessments separated by at least 77 days and at most 107 days.

Quarterly MDRO infection prevalence stayed steady with a slight decrease from 1.38% to 1.32% in 4 quarters. By the end of the first quarter, 0.70% of residents with no reported MDRO infections at baseline were reported to have MDRO

infections. This new infection rate increased to 0.80% and 0.93% in the second and third quarters. By the end of the third quarter, almost 2% of residents with no reported MDRO infections at baseline were reported to have at least 1 episode of MDRO infection.

DISCUSSION

This article explores the utility of MDS data for answering a number of important research and policy questions around prevalence and transmission of MDRO infections across care settings. Our findings show that there is a very high-volume patient flow between NHs and hospitals. At least 21.5% of all older adults' national hospital episodes involve an admission from or a discharge to an NH. Therefore, MDRO infections in one setting will have implications for MDRO infections in the other setting.

We have demonstrated that the MDS data capture useful demographic, clinical, and care transition data for hospital admissions and discharges. There are significant variations in MDRO infection prevalence in NHs across sex, age, and geographical groups. Findings include that, in NHs, male residents and younger residents are significantly more likely to have an active MDRO infection than are female residents and older residents. NHs in urban areas experience higher infection rates than do their rural counterparts. We have also demonstrated that MDS data can be used to assess MDRO transmissions across care settings. With MDS data from a longer time period, it is possible to better isolate the care setting in which MDRO infection onsets. Our findings indicate that MDRO infections are most likely to originate at NHs, followed by ACHs.

We recommend that MDS data be used as a monitoring tool and be combined with other data sets, such as HCUP, to provide a more complete picture of HAI transmissions across care settings to inform development of guidelines for prevention of HAIs.

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