Functional Disability and Nursing Resource Use Are Predictive of Antimicrobial Resistance in Nursing Homes

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OBJECTIVES: To use a simple measure of activities of daily living, wounds, and indwelling devices (urinary catheter, feeding tube) to predict prevalent, new, and intermittent multidrug-resistant organism (MDRO) acquisition in nursing home (NH) residents.

DESIGN: Secondary analysis, prospective cohort study.

SETTING: Southeast Michigan NHs (n = 15).

PARTICIPANTS: NH residents (N = 111, mean age 81) with two or more monthly visits (729 total).

MEASUREMENTS: Monthly microbiological surveillance for MDROs from multiple anatomic sites from enrollment until discharge or 1 year. The Arling scale, previously developed as a measure of NH residents' need (time-intensity) for nursing resources, was used to predict prevalent and time to new or intermittent acquisition (months) of methicillin-resistant *Staphylococcus aureus* (MRSA), vancomycin-resistant enterococci (VRE), and antibiotic-resistant gram-negative bacteria (R-GNB) colonization using multiple-failure accelerated time-factor survival analysis, controlling for comorbidity, hospitalization, and antibiotic use in the prior month.

RESULTS: One-fifth of participants had a wound, and one-third had a device. There were 60 acquisitions of MRSA, 56 of R-GNB, and 15 of VRE. Expected time to acquisition was less than 1 year for MRSA (median 6.7 months) and R-GNB (median 4.5 months) and more than 1 year for VRE (median 40 months). Arling score was associated with earlier new MRSA and VRE acquisition. A resident with only mild functional impairment and no device or wound would be expected to acquire MRSA in 20 months, versus 5 months for someone needing the most-intense nursing contact.

CONCLUSION: MDRO acquisition is common in community NHs. Need for nursing care predicts new MDRO acquisition in NHs, suggesting potential mechanisms for MDRO acquisition and strategies for future interventions for high-risk individuals (e.g., enhanced barrier precautions). **J Am Geriatr Soc 63:659–666, 2015.**

Key words: functional disability; multidrug-resistant organisms; nursing homes

Multidrug-resistant organisms (MDROs) are endemic in nursing homes (NHs), with prevalence rates surpassing those in hospitals.[1–4] Indwelling device use, prior antibiotic exposure, presence of a wound or pressure ulcer, and prior hospitalization are considered to be individual risk factors for colonization with MDROs.[5] Retrospective and cross-sectional studies have shown that older adults with greater functional disability are at greater risk of symptomatic infection[6,7] and asymptomatic colonization with MDROs whether they reside in NHs or have been transferred from a NH to acute care.[8–10] In a cross-sectional study, active surveillance for MDROs showed a dose–response relationship between a NH resident's overall functional disability burden and MDRO colonization.[8] Subsequently, a prospective study identified functional disability as an independent risk factor for NH residents to acquire new MDROs over 1 year of care.[9,11]

It was hypothesized that functional disability was related to MDRO acquisition because of greater need for contact with healthcare professionals. How many months, on average, it took for NH residents to become newly colonized with MDRO at each level of intensity of nursing care (defined according to functional impairment and need for other skilled nursing assistance) was measured.

METHODS

Data were analyzed from a prior prospective microbial study involving 15 community-based NHs in southeast Michigan. Details of the study design have been reported.[12] Briefly, this prospective observational study was conducted from October 2005 to January 2010. Participating NH facilities accepted people from local

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hospitals, but none were academic or hospital-based NHs. Bed size ranged from 71 to 161. Four sites were nonprofit or operated by the county government, and the remaining 11 were for-profit facilities. All residents with an indwelling device (urinary catheter or enteral feeding tube) were approached for recruitment. Upon enrollment of a resident with an indwelling device, a device-free resident was randomly approached for recruitment as a control. All participating residents were followed for a maximum of 12 months or until loss to follow-up, which occurred due to death, refusal to continue with monthly cultures, or device removal. The University of Michigan and Veterans Affairs Ann Arbor Health Care System institutional review boards approved this study. Written informed consent for enrollment was obtained from all participants or appropriate proxies.

Demographic data were recorded at enrollment, and clinical and microbiologic data were obtained at baseline and every month thereafter until death or discharge. Samples were collected monthly from the nares, oropharynx, groin, perianal area, and any wounds or device sites.[13] Standard microbiological methods were used to identify methicillin-resistant *Staphylococcus aureus* (MRSA), vancomycin-resistant *enterococcus* (VRE), and antibiotic-resistant gram-negative bacteria (R-GNB, to ciprofloxacin or ceftazidime) organisms. To test the hypothesis that higher nursing resource use would lead to shorter time to acquisition of MDROs, only residents with at least a baseline and one follow-up culture were included in the study.

Trained research personnel obtained participant data such as age at time of enrollment, sex, functional status, presence of indwelling device (urinary catheter or enteral feeding tube), and comorbid illnesses from medical records. Baseline function was assessed for severity of impairment in six activities of daily living (ADLs: bathing, toileting, dressing, feeding, walking, grooming) using the Lawton-Brody Physical Self-Maintenance Scale (PSMS, range 1–5,[14] 1 = independent with the ADL, 2 = needs reminders, 3 = needs moderate assistance, 4 = needs extensive assistance, 5 = needs full assistance or resistant to care). Comorbidity was calculated using the Charlson Comorbidity Index (CCI).[15] Data were also collected on time-varying variables such as hospitalization, antibiotic use, and presence of wounds or pressure ulcers in the prior 30 days.

Research by Arling and associates[16] was adapted to estimate each participant's need for nursing care, based on ADL impairment severity, device presence, and wounds. It was decided to use the Arling criteria because of their simplicity, reducing the variables that Medicare uses to determine NH case-mix[17] to a simpler set of variables that were subsequently validated in a time-motion study of nursing intensity of care.[16] The scale has excellent fit with relative observed nursing usage time (53% of variance).[16] The method classifies patients into six groups, using feeding dependence, overall ADL impairment, devices, and wounds to determine the groups. Each group is associated with a weight representing the ratio between average nursing time spent on care for that group and that spent on a normative group of residents in the same NH.

To convert the PSMS-based ADL impairments, disability of 4 or 5 (extensive or greater assistance) was converted to 2 ADL points in the Arling method, and disability of 2 or 3 (some assistance) was converted to 1 ADL point. An individual's ADL score using the Arling method is the sum of all ADL points (range 0–12).

The Arling groups (with their corresponding relative nursing usage weights) were as follows:

- Group 1 (1.79 weight): severe functional impairment (≤9 ADL points) AND (device OR wound)
- Group 2 (1.49 weight): severe functional impairment (≤9 ADL points) AND absence of device or wound.
- Group 3 (1.25 weight): moderate to severe impairment (≤7 ADL points) AND completely dependent for feeding
- Group 4 (0.95 weight): moderate to severe impairment (≤7 ADL points) but NOT completely dependent for feeding
- Group 5 (0.77 weight): mild to moderate impairment (5–6 ADL points)
- Group 6 (0.46 weight): mild or no impairment (<5 ADL points)

Criteria for Groups 1 and 2 were simplified (presence of any wound, whereas the original criteria specified daily wound care).[16] Thus, a participant was first assigned to a group based on the modified Arling criteria at baseline and then assigned the mean relative resource points for that participant's group.

Outcome variables were based on the results of MDRO cultures obtained at baseline and all follow-up visits. Positive colonization for any of the three MDROs studied (MRSA, R-GNB, VRE) was defined as a positive culture at any anatomic site (nares, oropharynx, groin, perianal area) or at any wound or device for that organism. Prevalent colonization was defined as positive culture at the baseline visit. A new acquisition was defined as positive colonization at a follow-up visit and negative at all sample sites the time before. Thus, time (months) to new asymptomatic colonization with MRSA, R-GNB, or VRE could be measured as three separate events.

Statistical Analysis

First, an individual-level cross-sectional observational analysis of prevalent MDROs (positive MRSA, R-GNB, or VRE culture found at the baseline as separate outcomes) was performed using unadjusted logistic regression, using all candidate variables, including the Arling scale, as univariate predictors.

Next, monthly surveillance samples were used to perform a longitudinal survival analysis to assess time (months) to MDRO acquisition. Rather than the standard methods of Cox regression, parametric survival analysis, which requires determination of the functional form of the hazard of event, was used. A parametric analysis allows for an estimate of mean time to event, or "life expectancy" in MDRO-free months, representing when half of the sample is expected to acquire an MDRO.

A repeated-failure model was also applied, which allowed time to re-colonization to be estimated in participants who were colonized transiently.[18,19] Application of this methodology is novel to the infection prevention literature. The approach captures the dynamic nature of MDRO transmission (transient vs persistent) in the NH

setting. In traditional time-to–first event survival analysis, valuable surveillance data for individuals who are intermittently colonized are discarded after the first occurrence. In the current study, participants who lost positive MDRO status across all of their cultured anatomical locations for 2 consecutive months could reenter the analysis and be at risk for intermittent (recurrent) colonization.

Two additional criteria were used as safeguards to ensure that a low-level of colonization was not misclassified as intermittent colonization. First, participants with MDROs at baseline (who were not eligible for initial acquisition) could become eligible for recurrent acquisition after negative cultures were obtained at all anatomical sites for two consecutive visits. Second, participants were conservatively considered to be persistently colonized (ineligible for recolonization) if an isolated negative culture was found between two positive cultures or if the last culture before study exit was an isolated negative culture.

The cumulative baseline hazard monotonically increased for the acquisition of MDROs over time, allowing for parametric survival analysis. The data best fit a log–logarithmic distribution using the lowest Akaike information criterion, allowing for fitting of an accelerated failure time survival model:[20]

$$\mathrm{Log}\,(T) = \alpha_0 + \alpha_1 X + \epsilon,$$

where T is time in months to MDRO acquisition (MRSA, R-GNB, VRE), α_1 is the acceleration time factor (a multiplicative factor of time to event per unit of X), and ε is the error term with the log-logarithmic distribution. Like a hazard ratio, an acceleration time factor (TF) less than 1 represents a shorter time to event (greater risk). The cumulative baseline hazard of acquiring a recurrent MDRO (second, third, fourth) was greater than and steeper over time than for initial MDRO acquisition. Therefore, the model considered a different baseline hazard according to initial versus recurrent acquisition.

For all three MDROs, the unadjusted effect of severity of impairment (six specific ADLs and the Arling scale), baseline age, sex, presence of indwelling device, and time-varying predictors (hospitalization, recent antibiotic use, presence of wound or pressure ulcer within 30 days) on prevalent MDRO and time to MDRO acquisition was tested. The Arling scale was focused on as the composite measure of interest, with multivariable controls for the presence of antibiotics, hospitalizations, and comorbidity introduced based on prior evidence.[1,8,10]

Table 1. Baseline Characteristics of the Longitudinal Analysis Sample (n = 111)

Characteristic	Value
Age, mean ± SD (range)	82 ± 11 (43–103)
Male, n (%)	32 (29)
Number of specimens collected per resident, mean ± SD (range)	6.1 ± 5.9 (2–13)
Residents MDRO positive at baseline (prevalent MDRO), n (%)	
MRSA	26 (23)
R-GNB	40 (36)
VRE	11 (10)
Residents acquiring ≥1 new colonizations within 12-month study, n (%)	
MRSA	48 (43)
R-GNB	43 (39)
VRE	14 (13)
MDRO acquisitions per resident during the 12-month study, mean ± SD (range)	
MRSA	0.54 ± 0.71 (0–3)
R-GNB	0.50 ± 0.71 (0–3)
VRE	0.14 ± 0.37 (0–2)
Residents with ≥1 devices (feeding or urinary tube) at baseline, n (%)	39 (35)
Residents with wounds or pressure ulcer (<30 days) at baseline, n (%)	22 (20)
Residents with recent (<30 day) use of any antibiotic at baseline, n (%)	48 (43)
Residents with a recent hospitalization (<30 days) at baseline, n (%)	27 (24)
Charlson Comorbidity Index, mean ± SD (range)	2.5 ± 1.5 (0–8)
Activity of daily living impairment at baseline, mean ± SD (range)[a]	
Bathing	3.6 ± 0.8 (2–5)
Toileting	3.8 ± 1.3 (1–5)
Feeding	2.7 ± 1.4 (1–5)
Dressing	3.6 ± 1.0 (1–5)
Grooming	3.4 ± 1.0 (1–5)
Ambulation	3.6 ± 0.8 (1–5)
Relative need for nursing care, n (%)[b]	
Group 6 (0.46 weight)	9 (8)
Group 5 (0.77 weight)	17 (15)
Group 4 (0.95 weight)	41 (37)
Group 3 (1.25 weight)	8 (7)
Group 2 (1.49 weight)	0 (0)
Group 1 (1.79 weight)	36 (32)

SD = standard deviation; MDRO = multidrug-resistant organism; MRSA = methicillin-resistant *Staphylococcus aureus*; R-GNB = antibiotic-resistant gram-negative bacteria; VRE = vancomycin-resistant *Enterococcus*; PSMS = Lawton and Brody Physical Self-Maintenance Scale.

[a] Defined as in the Lawton and Brody Physical Self-Maintenance Scale (range 1–5, higher scores indicate more-severe disability).

[b] Greater weight[16] indicates greater need, relative to a "standard" patient with a weight of 1. The criteria for Groups 1 and 2 were simplified from the original work by Arling and associates.

RESULTS

Of the 178 NH participants in the original study, this longitudinal analysis was conducted on the 111 with two or more visits (729 visits total). The number of visits (baseline plus monthly visits) per participant ranged from two to 13, and the mean number of samples collected was 6 (Table 1). The mean participant age for the analytical sample was 81; 20% had a wound. The baseline ADL ability of the participants, along with the nursing resource usage information, is detailed in Table 1. The flow of data is shown in Figure 1.

Predictors of Prevalent MDRO Colonization

All participants regardless of baseline colonization status were included in the initial analysis of prevalent MDRO colonization. Several characteristics predicted prevalent MDRO colonization in the NH setting: ADL dependence, presence of indwelling device, recent wound or pressure ulcer, recent antibiotic use, and recent hospitalization at baseline. More specifically and as expected, the 10 participants with prevalent MRSA colonization were more likely

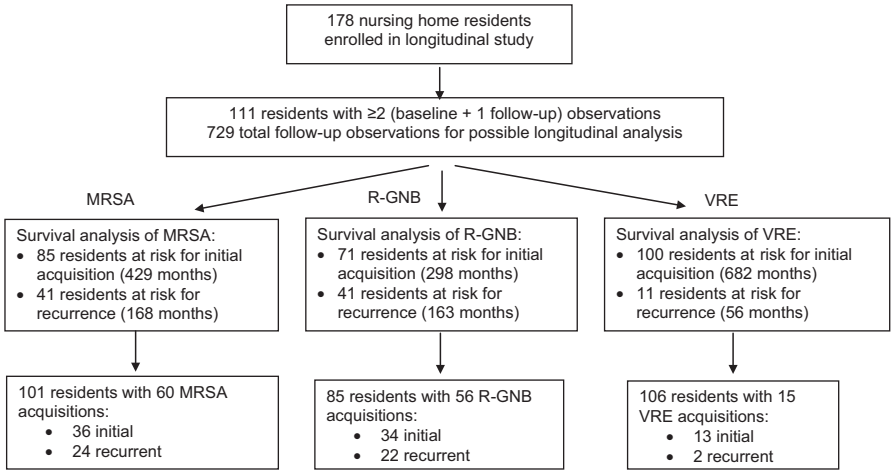

Figure 1. Flow of data from original monthly culture data set to survival analysis datasets. This figure describes the flow of data from the 178 nursing home residents in the original study to the longitudinal analysis on 111 residents. The analytical data set for the survival analysis was specific to each organism. Residents who were persistently colonized throughout the entire study with that organism could not be at risk for acquisition of that organism. Once positive for an organism, a resident with continued positivity also stopped contributing time at risk. If a resident became negative for at least two consecutive cultures, he or she could reenter the study and contribute to time at risk for recurrence. MRSA = methicillin-resistant *Staphylococcus aureus*; R-GNB = antibiotic-resistant (ceftazidime or ciprofloxacin) gram-negative bacteria; VRE = vancomycin-resistant enterococci.

Table 2. Unadjusted Acceleration Time Factor Survival Models Predicting Months to Initial Multidrug-Resistant Organism Acquisition

Sample Characteristics and Predictors	Initial Methicillin-Resistant *Staphylococcus aureus* Acquisition	Initial R-GNB Acquisition	Initial Vancomycin-Resistant Enterococci Acquisition
Characteristic			
Time at risk, months	429	298	682
Residents, n	85	71	100
New initial acquisition events, n	36	34	13
Predictor, acceleration time factor (95% confidence interval)[a]			
Age (per year)	1.00 (0.97–1.03)	0.97 (0.93–1.00)	0.99 (0.94–1.04)
Male	1.51 (0.69–3.31)	3.18 (1.20–8.39)	0.77 (0.23–2.55)
Arling score (need for nursing care, per point in relative weight)	0.33 (0.17–0.64)	0.52 (0.21–1.27)	0.24 (0.07–0.87)
Impairment in activities of daily living			
Feeding	0.81 (0.64–1.02)	0.75 (0.58–0.98)[b]	0.73 (0.50–1.09)
Bathing	0.80 (0.55–1.15)	0.64 (0.41–1.00)	0.62 (0.30–1.30)
Dressing	0.74 (0.54–1.01)	0.71 (0.50–1.02)	0.58 (0.28–1.23)
Grooming	0.81 (0.61–1.07)	0.77 (0.55–1.10)	0.75 (0.41–1.39)
Walking	0.77 (0.52–1.15)	0.48 (0.30–0.77)[b]	0.50 (0.23–1.00)
Toileting	0.79 (0.62–1.00)	0.65 (0.50–0.84)[b]	1.00 (0.67–1.50)
Any device	0.33 (0.18–0.59)	0.96 (0.38–2.41)	0.58 (0.18–1.90)
Any wound or ulcer in 30 days	0.43 (0.17–1.08)	2.18 (0.27–17.86)	0.15 (0.03–0.69)[b]
Comorbidity	1.01 (0.82–1.25)	0.99 (0.76–1.30)	0.75 (0.52–1.07)
Any hospitalization in 30 days	1.18 (0.22–6.23)	0.43 (0.10–1.87)	0.11 (0.02–0.55)[b]
Any antibiotics in 30 days	0.85 (0.40–1.83)	0.61 (0.23–1.61)	0.20 (0.05–0.74)[b]

Example interpretation of acceleration time factor: Time to acquisition of antibiotic-resistant (ceftazidime or ciprofloxacin) gram-negative bacteria (R-GNB) for a resident with complete dependence in walking (Level 4) is expected to be 48% (roughly twice as fast) of that of a resident with moderate dependence in walking (Level 3).

[a] Interpretation of the time factor is similar to a hazard ratio, in that a value <1 is protective, and a value >1 represents greater risk.

[b] $P < .05$.

than the 101 who were not colonized at baseline to have a higher Arling scale score (1.6 vs 1.1, $P = .002$), an indwelling device (70% vs 32%, $P = .02$), a recent hospitalization (70% vs 20%, $P < .001$), or a wound or pressure ulcer (50% vs 17%, $P = .01$). They also needed more help with bathing (severity score 4.2 vs 3.5, $P = .02$), eating (severity score 3.8 vs 2.6, $P = .01$), dressing (severity score 4.3 vs 2.6, $P = .03$), and grooming (severity score 4.1 vs 3.4, $P = .04$). Participants with prevalent R-GNB colonization (n = 26) were more likely than those not

colonized (n = 85) at baseline to have an indwelling device (58% vs 28%, $P = .006$), higher Arling score (1.4 vs 1.1, $P = .003$), greater need for help with walking (severity score 4.0 vs 3.5, $P = .003$), recent antibiotic use (65% vs 36%, $P = .009$), a recent hospitalization (54% vs 15%, $P < .001$), and a wound or pressure ulcer (35% vs 15%, $P = .03$). Similarly, participants with prevalent VRE colonization (n = 5) were more likely than those without (n = 106) to have an indwelling device (80% vs 30%, $P = .03$), recent antibiotic use (100% vs 41%, $P = .009$), and recent hospitalization (100% vs 21%, $P < .001$). These results demonstrated that individual risk factors as well as the composite Arling scale were consistently predictive of prevalent MDRO colonization.

Time to New and Recurrent MDRO Acquisition

There were 60 instances of MRSA acquisition in participants, 56 of R-GNB, and 15 of VRE (Figure 1). The median predicted time to acquisition for MRSA and R-GNB was less than 1 year (initial MRSA 7.6 months, recurrent 4.6 months, overall (initial or recurrent acquisition) 6.7 months; initial R-GNB 5.1 months, recurrent 4.5 months, overall 4.9 months). Because there were so few acquisitions of VRE, median predicted time to acquisition exceeded 12 months (initial 42.0 months, recurrent 13.2 months, overall 39.7 months).

The unadjusted analyses (Table 2) showed that severity of walking, feeding, and toileting disability was associated with shorter time to initial R-GNB acquisition. Walking disability was also associated with shorter time to initial VRE acquisition. Hospitalization, wounds or pressure ulcers, and antibiotic use in the past 30 days were also associated with shorter time to initial VRE acquisition. A hospitalization had occurred within 30 days of only 3%, 6%, and 23% of the new acquisitions of MRSA, R-GNB, and VRE, respectively (not shown). On univariate analysis of time to recurrent acquisition (not displayed), none of the variables (including Arling score) were significant except for age (greater time to MRSA acquisition, $P = .04$), comorbidity (less time to R-GNB acquisition, $P = .049$), and feeding dependency (less time to VRE acquisition, $P = .02$).

As hypothesized, higher nursing resource usage was correlated with shorter time to MRSA and VRE acquisition. On multivariable analysis, greater need for overall nursing according to Arling score was independently associated with earlier MRSA and VRE acquisition, independent of antibiotic use, hospitalization, or comorbidity. Predicted time to MDRO acquisition per additional point on the scale was multiplied by a TF of 0.33 (95%

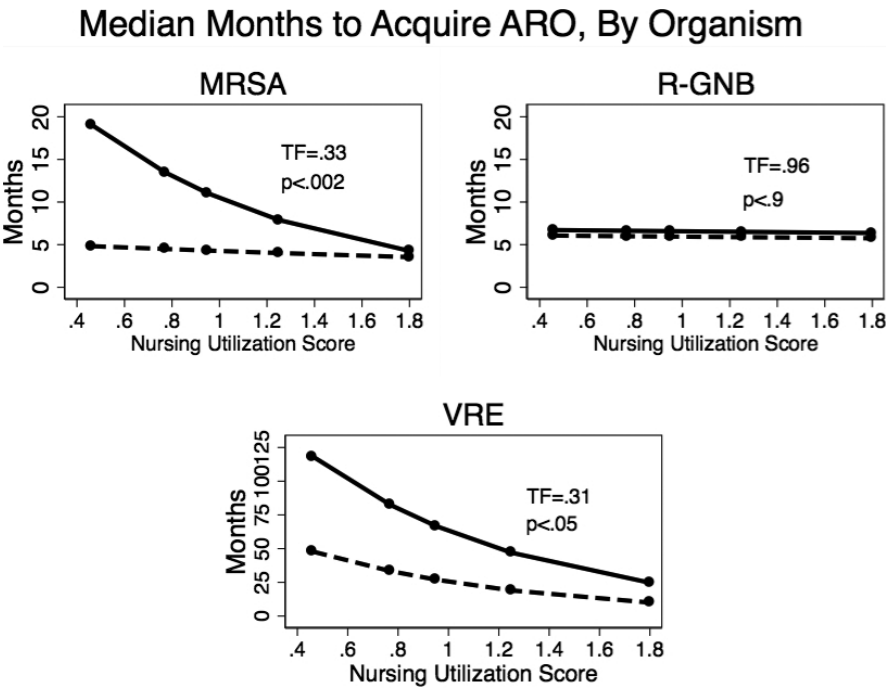

Figure 2. Greater need for nursing care predicts shorter time to acquisition of methicillin-resistant *Staphylococcus aureus* (MRSA) and vancomycin-resistant enterococci (VRE) but not antibiotic-resistant (ceftazidime or ciprofloxacin) gram-negative bacteria (R-GNB). Graphical display of expected time to multidrug-resistant organism (MDRO) acquisition for MRSA, R-GNB, and VRE using accelerated failure-time model stratified according to initial versus recurrent acquisition event. The *y*-axis displays the predicted number of months to acquisition for initial (solid line) and recurrent (dashed line) MDRO colonization. Residents' baseline need for nursing resources[16] (an ordinal variable assigned with relative weights, where a higher score = more need for care), expressed as a continuous variable in this analysis, is indicated on the *x*-axis. Solid circles represent the predictions for nursing resource usage groups. All predicted times to events are controlled for wounds and pressure ulcers (within 30 days, time varying), hospitalizations (within 30 days, time varying), antibiotic use (within 30 days, time varying), and comorbidity. For example, a resident with the least-intense nursing requirement (0.46 relative weight) would be expected to acquire a new MRSA colonization in 20 months, versus 5 months for residents needing the most-intense nursing (1.8 relative weight).
ARO = antibiotic-resistant organism.

CI = 0.16–0.66) for MRSA acquisition and 0.31 (95% CI = 0.10–0.95) for VRE acquisition (Figure 2). Predicted time to initial MRSA acquisition was 20 months for the lowest need for nursing care and 5 months for the highest, whereas time to a reacquisition event did not vary according to Arling score and was, on average, 5 months (Figure 2). Time to R-GNB colonization could not be predicted using the Arling score.

DISCUSSION

This prospective longitudinal study of NH residents under active surveillance for MDRO acquisition found that the Arling scale, a simple and validated clinical assessment of nursing need based on severity of ADL impairment, and presence of indwelling devices and wounds or pressure ulcers[16] predicted which residents had preexisting MDRO colonization. It also showed that mean time to new MDRO acquisition was less than 1 year for MRSA and R-GNB organisms. After controlling for known risk factors such as recent hospitalizations and antibiotic use, it was found that residents with greater nursing need, quantified using the Arling scale, had shorter time to MRSA and VRE acquisition.

Colonization by MRSA[21,22] or VRE[22–24] is associated with infection by that organism, although less so for R-GNB.[22,25] The results of the current study suggest potential strategies to prevent MRSA and VRE acquisition in NHs. From a resident perspective, residents at greater risk, whenever that risk arises, should be targeted. From a facility perspective, the results suggest that acquisition occurs within 6 months of observation, underscoring the urgency of implementing surveillance and prevention efforts by identifying high-risk residents early in their NH stay.

A prior study of NH residents showed that limited mobility and functional disability are associated with greater prevalence of asymptomatic MRSA.[11] Functional disability has also been associated with high-level gentamicin-resistant enterococcal colonization.[10] Furthermore, it has been shown that need for assistance with more than three ADLs increases the risk of MRSA surgical site infections in older hospitalized adults.[6] Using active surveillance in a cross-sectional study of NH residents, a dose-response relationship between functional disability and R-GNB colonization was found.[8]

Although prior research has identified separate risk factors, the current study used a parsimonious composite measure (the Arling scale) that reflects risk factors for MDROs and assigns greater weight to individuals who require more nursing contact time. The results suggest that greater and more-intense contact with healthcare providers, especially in NH residents with severe ADL impairment and with potential entry points such as indwelling devices and wounds,[16] increases the risk of MDRO colonization. Residents who are at heightened risk of MDRO colonization should therefore be targeted for enhanced barrier precautions.

Although this study was not adequately powered to determine whether certain individual ADLs predispose to MDRO acquisition, dressing and toileting, ADL care that requires skin-to-skin contact with the care provider and contact with residents' bacteria-rich skin regions, are predictors of new MRSA acquisition. In older hospitalized adults with surgical site infections, it has been shown that assistance in bathing or dressing increases the risk of MRSA surgical site infections.[6] Although it is probable that contact-intense ADL dependency reflects underlying severity of illness, it may be that specific ADL dependency increases the opportunity for pathogen transmission from healthcare workers to residents and vice versa.

A higher Arling score did not differentiate time to acquisition for R-GNB from a lower score. One reason may be that R-GNB resides specifically in the genitourinary tract and that R-GNB acquisition was therefore associated with severe toileting dependency rather than the Arling scale. Also, combining different organisms and patterns of resistance as a single R-GNB may have resulted in weaker relationships between risk factors and transmission than with VRE and MRSA. Future studies should be designed to identify epidemiologically significant R-GNB species that are likely to be transmitted to other frail NH residents or cause infections in this population.

Prior research[8,11] considered poor function and MDRO acquisition in a cross-sectional manner and reported time to colonization only in colonized residents. In contrast, this research used survival analysis to predict each resident's MDRO-free time at enrollment or the median expected number of months to acquire MDRO. In future surveillance research, a delay in time to acquisition should be considered as an outcome measure of successful infection prevention.

Several avenues for future research were identified. Less contribution of recent hospitalization to acquisition of MRSA and R-GNB (<10% of new cases) was found than expected, which leads to speculation that the facility is the source of the MDROs, facilitated by resident characteristics and need for contact-intense nursing, but the role of healthcare workers' assistance, environmental contamination, and interaction with resident-level factors that can lead to new MDRO acquisitions requires further study. Second, future studies should address whether current infection prevention interventions such as active surveillance and feedback, as well as use of barrier precautions when providing help with contact-intense ADLs, leads to less MDRO transmission in the NH setting. A single-NH study[13] found that preemptive gowning and gloving of all residents prevents transmission of *Klebsiella* pneumonia from resident to resident. A trial of preventive barrier intervention for residents with indwelling devices is now under way at 12 NHs.[26,27] A third future direction would be to use Resource Utilization Group scores, which NH, rather than research, staff routinely collect, as a way to stratify contact-intense residents who should receive enhanced MDRO and infection prevention efforts.

One weakness of this study was that new VRE acquisition was uncommon, limiting power to detect an effect of most of the predictor variables on new VRE acquisition. Limitations of the current active surveillance methods include potential false-positive errors due to fluctuating levels of colonization rather than true recolonization. Second, the time that healthcare workers spent providing assistance with ADLs was not quantified. Third, the data lacked enough power to include facility-level variables for any of the MDRO models. Thus, the analysis addressed

only how resident-level needs contributed to MDRO acquisition. Fourth, the sample size was too small to test for the effect of individual ADLs on MDRO acquisition. Future research is needed to examine whether there is facility-level variation in the link between specific ADLs and new MDRO acquisition in NH residents, which could lead to more-targeted preventive interventions. Last, the newer Resource Utilization Group scores include variables other than the Arling scale that more accurately predict nursing usage.[17,28] More-detailed variables (e.g., specific rehabilitation services and behavior) that marginally contribute to nursing usage beyond ADLs (although none more important than ADLs) could be explored in future studies of MRDO acquisition.

The strength of this study is the use of prospective comprehensive monthly collection and microbiological testing of specimens from NH residents for the presence of MDROs, which is crucial for detecting new asymptomatic MDRO colonization. To the knowledge of the authors, this is the first report of a comprehensive evaluation of nursing resource usage, as well as the severity of functional disability and its effect on new MDRO acquisition. The current practice of identifying resistance in NH residents using passive surveillance methods represents just the "tip of the iceberg" of all colonized residents. With sensitive multisite, multivisit surveillance, it was possible to show the underlying magnitude of new MDRO colonization in these residents. Multiple resistance patterns for R-GNB were also tested for, increasing sensitivity for new MDRO acquisition. Last, a network of multiple NHs in southeast Michigan with varying bed size and facility characteristics was used, broadening the potential generalizability of the results.

In conclusion, contact-intense ADLs that were associated with shorter time to MDRO colonization were identified, presenting an opportunity for future interventions to prevent MDROs in NH residents.

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Author Contributions: All authors contributed to this paper. Dr. Min had full access to all of the data in the study and takes responsibility for the integrity of the data and the accuracy of the data analysis.

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