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Original Article

C. auris and neighborhood socioeconomic vulnerability in the state of Maryland from 2019 to 2022

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Abstract

Background: *Candida auris* is an emerging fungal pathogen increasingly recognized as a cause of healthcare-associated infections including outbreaks.

Methods: We performed a mixed-methods study to characterize the emergence of *C. auris* in the state of Maryland from 2019 to 2022, with a focus on socioeconomic vulnerability and infection prevention opportunities. We describe all case-patients of *C. auris* among Maryland residents from June 2019 to December 2021 detected by Maryland Department of Health. We compared neighborhood socioeconomic characteristics of skilled nursing facilities (SNFs) with and without *C. auris* transmission outbreaks using both the social vulnerability index (SVI) and the area deprivation index (ADI). The SVI and the ADI were obtained at the state level, with an SVI ≥ 75th percentile or an ADI ≥ 80th percentile considered severely disadvantaged. We summarized infection control assessments at SNFs with outbreaks using a qualitative analysis.

Results: A total of 140 individuals tested positive for *C. auris* in the study period in Maryland; 46 (33%) had a positive clinical culture. Sixty (43%) were associated with a SNF, 37 (26%) were ventilated, and 87 (62%) had a documented wound. Separate facility-level neighborhood analysis showed SNFs with likely *C. auris* transmission were disproportionately located in neighborhoods in the top quartile of deprivation by the SVI, characterized by low socioeconomic status and high proportion of racial/ethnic minorities. Multiple infection control deficiencies were noted at these SNFs.

Conclusion: Neighborhood socioeconomic vulnerability may contribute to the emergence and transmission of *C. auris* in a community.

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Background

Candida auris is an emerging multidrug-resistant fungal pathogen that is increasingly recognized as a cause of healthcare-associated infections and outbreaks in healthcare settings. The first few cases in the United States were described in 2016 following an alert issued by the Centers for Disease Control and Prevention (CDC), with subsequent spread in healthcare settings associated with a high burden of colonization among individuals in ventilator-capable skilled nursing facilities (SNFs).[1,2] The first case-patient of *C. auris* transmission in Maryland was identified in June 2019.

The ability of *C. auris* to colonize the skin of individuals as well as contaminate the surrounding environment contributes to transmission in congregative settings.[3,4] Prior outbreaks have been attributed to poor existing infection control practices including poor hand hygiene, inadequate environmental cleaning, and lack of proper disinfection agents.[5] Existing research has highlighted individual patient risks factors associated with *C. auris* colonization including mechanical ventilation, antifungal treatment, prior frequent hospitalizations and residence in SNF.[2]

Other emerging infectious diseases, including COVID-19 and Mpox, have disproportionately affected vulnerable communities, and there is growing interest in examining health disparities in healthcare-associated infections as well as underlying systemic structural contributors to antimicrobial resistance.[6,7] One case–control study from 2016 to 2018 in New York among 60 *C. auris* case-patients residing in ventilated capable SNFs noted that residents with and without *C. auris* did not differ by age, sex, or race/ethnicity.[2] However, measures of socioeconomic vulnerability – at either the individual or facility-level - have not yet been systematically evaluated among patients who are infected or colonized with *C. auris*. There is also a lack of data on which neighborhood socioeconomic characteristics and vulnerability indices can accurately identify infectious disease risk in SNFs.

Recent studies have recognized that neighborhood deprivation is associated with gaps in staffing and resources,[8] which may

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preclude implementation of optimal infection control practice. This may be compounded by intersectionality between individual- and facility-level disadvantages, producing greater vulnerability than either, by itself. For example, an individual with medical risks that are unaddressed due to poor access to care may also reside in a SNF with greater disadvantage. There are opportunities for using both quantitative and qualitative findings together to provide a better groundwork for sustainable intervention.[9]

In this study, we describe characteristics of patients and facilities with *C. auris* in the state of Maryland with a focus on socioeconomic vulnerabilities. In this exploratory work, we evaluate the association of two different vulnerability indices and their association with *C. auris* risk at both the individual level and facility level. We also describe findings from infection control assessments conducted in Maryland facilities suspected of having *C. auris* transmission. Finally, we propose a conceptual model that combines patient-level and facility-level medical and social vulnerabilities in the transmission of this pathogen and thus may provide direction for future prevention and control strategies.

Methods

We conducted a mixed-methods study to characterize the emergence of *C. auris* in the state of Maryland from 2019 to 2022, with a focus on socioeconomic vulnerability and infection prevention opportunities.

During this period, the Maryland Department of Health (MDH) investigated all *C. auris*-positive clinical and surveillance cultures through basic epidemiologic methods including contact tracing for additional case finding. Infection control programs of healthcare facilities with suspected *C. auris* transmission were assessed by MDH using a state-specific Infection Control Assessment and Response (ICAR) tool modified from the CDC ICAR tool.[10]

We first performed a descriptive analysis of all case-patients of *C. auris* identified in Maryland from June 2019 to December 2021. We defined case-patients as any individual >18 years old that had *C. auris* detected on either a clinical or surveillance (screening) sample obtained at a Maryland healthcare facility. Screening or surveillance *C. auris* specimens, consisting of composite axilla/groin skins swabs obtained during point prevalence colonization screenings, were tested via polymerase chain reaction by the Maryland Public Health Laboratory (MDPHL). Clinical *C. auris* case-patients were identified by culture from different body sites during routine clinical care and reported to the health department.

Clinical information on potential patient-level risk factors was obtained from healthcare facilities and from the Chesapeake Regional Information System for our Patients (CRISP).

Socioeconomic inequalities and their relationship to poor health outcomes have been described using vulnerability indices including the social vulnerability index (SVI) and the area deprivation index (ADI). The ADI is a publicly available measure created to define neighborhood socioeconomic status at the census block-group level based on 17 domains representing poverty, education, and housing with data from the United States Census and the American Community Survey.[11,12] The CDC SVI tool[13,14] is a measure created to identify socially vulnerable populations at the census tract level based upon 16 social factors divided into four distinct themes: (1) socioeconomic status, (2) household characteristics, (3) racial and ethnic minority status, and (4) housing type and transportation. Both ADI and SVI are expressed as percentile calculated at either the state or national level. State-level percentiles were utilized in this study for better discrimination. State ADI ranges from 1 to 10 and SVI 1–100, with higher percentiles indicating greater socioeconomic disadvantage. We split the ADI into quintiles and SVI into quartiles to better analyze and characterize the distribution of patients given the nonlinear effects. We defined severely disadvantaged as neighborhoods noted to be within the top quintile of deprivation ($ADI \geq 8$) of ranking for ADI and census tracts noted to be in the top quartile ($SVI \geq 75$) of ranking for SVI. Data obtained were from the 2020 ADI and SVI Index which both draw from American Community Survey 2020 encompassing 5-year data 2016–2020.

Table 1. Percentage of individuals with *C. auris* colonization or infection who resided in severely disadvantaged neighborhoods by theme. Severely disadvantaged was defined as the top quartile of disadvantage (SVI> = 75) within the state

Social vulnerability index (SVI) variable	Percentage of *C. auris* patients residing in neighborhoods with severe SVI indices (SVI = >75) n = 116
Overall: SVI	41% (47)
Socioeconomic status: Theme 1	40% (46)
Unemployed	34% (39)
No high school diploma	37% (43)
Below 150% poverty	28% (32)
No health insurance	39% (45)
Household characteristics: Theme 2	41% (47)
Age 17 or younger	28% (32)
Aged 65 or older	16% (19)
Civilian with a disability	15% (17)
English language proficiency	41% (47)
Racial and ethnic minority status: Theme 3	59% (68)
Housing type: Theme 4	28% (33)
Crowding	43% (50)

We obtained patient home addresses from CRISP and utilized the latest address prior to detection of *C. auris*. Addresses associated with SNF case-patients were replaced by their addresses before admission to a facility. Case-patient addresses and SNF addresses were geocoded and assigned both a census tract and census block to calculate the SVI and ADI, respectively. The average ADI of the surrounding blocks was used for SNFs located in areas without a designated ADI.

We summarized patient and SNF characteristics using descriptive statistics. We compared characteristics of SNFs with and without identified *C. auris* transmission using χ^2 test for categorical variables. Transmission was defined as ≥ 2 epidemiologically linked case-patients at the same SNF. All statistical analyses were completed using STATA.

From June 2019 to December 2022 the MDH Infection Prevention and Control (IPC) team, consisting of nurses, physicians, and public health professionals, conducted ICARs at 12 unique SNFs with confirmed transmission of *C. auris* from June 2019 to December 2022. ICARs included prevention and control audit tools tailored to Maryland facilities that included the following domains: hand hygiene, staffing, environment of care,

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Table 2. Comparison of severe social vulnerability index (SVI> = 75) between skilled nursing facilities with and without identified *C. auris* transmission

Severe social vulnerability index indices (SVI = >75)	All facilities N = 213	Facility without transmission No (199)	Facility with transmission Yes (14)	*P* value
Overall: SVI	74 (35%)	69 (35%)	5 (36%)	0.94
Socioeconomic status: Theme 1	51 (24%)	45 (23%)	6 (43%)	0.09
Unemployed	49 (23%)	42 (21%)	7 (50%)	0.01
No high school diploma	58 (27%)	52 (26%)	6 (43%)	0.17
Below 150% poverty	62 (29%)	57 (29%)	5 (36%)	0.57
No health insurance	37 (17%)	33 (17%)	4 (29%)	0.25
Household characteristics: Theme 2	75 (35%)	70 (35%)	5 (36%)	0.97
Age 17 or younger	38 (18%)	38 (19%)	0 (0%)	0.07
Aged 65 or older	101 (47%)	95 (48%)	6 (43%)	0.72
Civilian with a disability	74 (35%)	69 (35%)	5 (36%)	0.94
Racial and ethnic minority status: Theme 3	36 (17%)	25 (13%)	11 (79%)	0.00
Housing type: Theme 4	110 (52%)	105 (53%)	5 (36%)	0.22
Group quarters	195 (92%)	182 (92%)	13 (93%)	0.86

environmental services, and wound care. We subsequently analyzed the source text documents containing those ICAR reports using Nvivo 11 (QSR International, Burlington, MA) for qualitative content analysis. Four IPC experts performed conventional content analysis on two randomly selected assessments to create a coding manual based upon common infection control observations. One reviewer manually coded the assessments and categorized emergent themes into overarching infection control domains and subthemes supported by the strongest observations.

This study was determined as exempt by the MDH institutional review board.

Results

Epidemiologic analysis

Individual case-patient-level analysis

Between June 2019 and December 2021, 140 individuals tested positive for *C. auris* in Maryland. Of these, 119 (85%) were detected by the MDPHL, while 21 case-patients were detected through testing at other laboratories. Of a total 144 samples positive for *C. auris*, the most common samples were axilla/groin surveillance swabs (99), blood cultures (16), urine cultures (14), and wound cultures (4). Overall, 46 (33%) of case-patients had a positive clinical culture during this period. The overall positivity rate among total 4499 surveillance (screening) tests for *C. auris* submitted to the MDPHL during this period was 2.7%.

The median age of *C. auris* case-patients was 68 years (IQR 53–74), and 91 (65%) were male. Sixty (43%) case-patients were residents of SNFs; 37 (26%) were mechanically ventilated, 87 (62%) had a documented wound, 49 (35%) had a documented feeding tube, and 29 (21%) had central lines in place. Thirty-nine of 140 (28%) case-patients died within 90 days of a positive *C. auris* test. Case-patients had home addresses from 7 different states; 122 (87%) had a home address in the state of Maryland. Of 116 individuals with an identifiable home street address in Maryland, the median state ADI was 6 (IQR 4–8). Thirty-three (28%) of case-patient home addresses were located in areas in the top quintile of deprivation based on state ADI (ADI> = 8). Statewide estimates for SVI showed that *C. auris* case-patient home addresses had a median SVI in the 68th percentile (IQR 37–85), with 47 (41%) located in areas in the top quartile of deprivation (SVI> = 75) (Table 1).

Skilled nursing facility-level analysis

Fifteen SNFs had likely transmission of *C. auris* between June 2019 and December 2022. Fifty percent (8/16) of ventilator-capable SNFs had noted transmission compared to 3% (7/209) of SNFs without ventilator capability. ADI was available for 212 SNFs including all 15 with noted *C. auris* transmission. The Maryland state median ADI of all 212 SNFs was 6 (IQR 5). Based on ADI, 31% of all Maryland SNFs and 40% of all Maryland ventilator-capable SNFs are located in the top quintile of deprivation (ADI> = 8). There was no statistically significant difference in ADI between SNFs with and without *C. auris* transmission. Data on SVI was available for 213 SNFs including 14 with noted *C. auris* transmission. Based on SVI, 35% of all Maryland SNFs are located in areas in the top quartile of deprivation. The overall proportion of severe SVI between SNFs with and without *C. auris* transmission did not differ. However, SNFs with *C. auris* transmission were significantly more likely to be located in areas in the top quartile of deprivation due to unemployment and minority status, compared to SNFs without identified transmission (Table 2).

Qualitative analysis: ICARs

Twelve of 15 SNFs with confirmed *C. auris* transmission had assessments available to be analyzed. Observations on hand hygiene revealed inconsistent access to alcohol-based hand rub and missed opportunities for hand hygiene. Education of staff surrounding *C. auris* was often lacking with notable gaps. Wound care observations were remarkable for lack of consistent use of aseptic technique and potentially contaminated supplies taken out of patient rooms at multiple facilities. Review of environmental cleaning processes revealed gaps in multiple areas including high-touch surfaces, maintenance, availability of cleaning supplies, and proper contact time (Table 3).

Table 3. Summary of findings from infection control and response audits of skilled nursing facilities with *C. auris* transmission (N = 12)

Domain number of assessments with observations (total = 12)	Observations	Supporting quotes
Hand hygiene		
ABHR and availability (10)	• 2 facilities had access to alcohol sanitizer throughout the units and in patient rooms. • 8 facilities were noted to have inconsistent access to ABHR. • Common themes included: lack of ABHR in hallways or patient rooms, ABHR far from resident care area in the room, and expired or out-of-order units.	"One unit had a few ABHR dispensers in the hallway but none in the resident rooms due to safety concerns. Some staff had personal ABHR but not all of them have this available."
Audits and adherence (10)	• 4 assessments noted that facilities performed hang hygiene audits, but 3 of these did not calculate rates or feed this information back to the units. • 2 facilities did not perform hand hygiene audits at all. • All 10 observations where hand hygiene was observed noted at least one staff member that missed an opportunity for hand hygiene, frequently during wound care, respiratory care, or meal service. • Hand hygiene compliance rates were calculated for multiple facilities and ranged between 25 and 60%.	"Staff were observed not performing HH during resident care. Respiratory therapy (RT) staff was observed not changing gloves and performing HH after cleaning a tracheostomy site."
Staffing, training, and auditing (9)	• The most common schedule for training was during onboarding orientation coupled with annual competencies. • Length of orientation for EVS ranged from 3 to 5 days and two facilities noted that their EVS staff had monthly education, but it was unclear how topics were selected. • Education on isolation precautions was not evident in many facilities.	"The facility has provided education on C. auris, but we were not able to confirm if EVS staff were included in this education." "Multiple staff (e.g., nursing, respiratory therapist) who were interviewed were not familiar with CRAB or C. auris and how it is transmitted." "Observed EVS staff not aware which residents were positive for C. auris. Therefore, staff were not aware which rooms required disinfectants effective against *C. auris*."
Wound care		
Availability of supplies (7)	• 6 noted having infection control gaps in availability and management of supplies. • Common themes included lack of disinfectant wipes on the wound care cart, storage of open supplies in the wound care cart, storage of wound supplies in inappropriate places and unlabeled supplies for patients	"Wound care staff brought a large pack of gauze into the resident's room and placed unused gauze back into the wound care cart." "The cart storing wound care and procedure supplies had multiple opened items inside. The top of the procedure cart had multiple patient supplies."
Aseptic technique (6)	• 5 noted a break in aseptic technique. • Common observations were lack of hand hygiene when changing gloves; failure to clean and disinfect the surface use for wound care supplies before and after use; and incorrect disinfection of scissors. In addition, multiple facilities were noted to be using wound cleanser spray incorrectly.	"Wound care staff was observed using wound cleanser spray by spraying directly onto the wound. This can cause splash-back to the wound care bottle causing contamination. The wound care spray bottle was not labeled specifically for the resident."
Environment of care (10)	• Common themes included incorrectly stored supplies making it difficult to tell whether items were clean or dirty. • Handrails were noted to be damaged making it difficult to clean and disinfect. • Geri-chairs and wheelchairs were noted to be improperly stored or used to hold patient items or soiled items. • Cardboard boxes were used to store PPE and medical supplies. • Resident rooms were noted to be cluttered making it difficult to clean and disinfect. Open packages were noted inside carts, and it was unclear whether they had entered a patient's rooms.	
Environmental services		
High tough surfaces (11)	• Only one facility was noted to be performing fluorescent markers audits but upon observation was noted to miss high-touch areas during the cleaning process. 2 Fluorescent gel audits were performed during observations and the marker remained on critical areas. • 2 facilities were noted to have a good understanding of the cleaning process for high-touch surfaces. • 8 facilities had deficiencies in cleaning high-touch surfaces on observations.	"Fluorescent gel was used to mark a vital signs machine and a glucometer. After the staff used the equipment, the fluorescent marker on the vital signs machine remained on all the areas placed on both the vital signs machine and glucometer." "Items which are high-touch surfaces in the room were not cleaned and disinfected daily (e.g., the front of the ventilators, tube feeding pumps, IV pumps)."

(*Continued*)

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Table 3. (*Continued*)

Domain number of assessments with observations (total = 12)	Observations	Supporting quotes
	• Common themes include cluttered surfaces making cleaning difficult and overall missed cleaning of remotes, bedrails, etc. • Lastly, 5 facilities were noted to have poor knowledge of cleaning schedule for high-touch surfaces notably surrounding ventilators and only cleaning when visibly soiled.	
Availability of cleaning supplies (11)	• 2 facilities were noted to have sufficient supplies throughout the community, while 5 had supplies in only some areas. • Supplies were missing in hallways, near vital sign machines and wound care carts. • Only 5 of 11 observations were strictly using cleaning products that are approved to kill *C. auris*. • Common themes included having multiple disinfectants on a floor with at least one product that does not kill *C. auris*; staff not aware which product should be used for patients with *C. auris*; and expired cleaning products.	"Staff was not aware that they were supposed to use bleach agents for a resident who was colonized with C. auris." "Staff were using (disinfectants) interchangeably because they were not aware of the difference."
Contact time (6)	• Multiple observations noted staff were unaware of contact time and would immediately use water after using cleaning products to rinse. • Some staff were aware of the concept of contact time but did not know the specific times for certain products or had incorrect contact times. • 2 observations noted that staff used the incorrect order of cleaning a patient room.	"During the visit, two staff interviewed were not familiar with the contact time for disinfectants used in the facility." "Some items or areas lack cleaning schedules and processes to ensure daily cleaning and cleaning between patient use."

Discussion

In this mixed-methods study of the first 140 *C. auris* case-patients identified in the state of Maryland, we found both individual-level and facility-level indices of neighborhood socioeconomic vulnerability to be associated with *C. auris*. Case-patient residence in SNFs and presence of wound(s) were frequent, and infection control deficiencies in SNFs were identified.

In our individual-level analysis of neighborhood characteristics of *C. auris* case-patients in Maryland, we found that this cohort belonged to neighborhoods that are less insured, have lower socioeconomic status and higher concentrations of racial/ethnic minorities, relative to the Maryland average. Similarly, 28% of case-patients resided in neighborhoods that were in the top quintile of deprivation by the ADI, a measure that describes socioeconomic disadvantage. However, it is unclear if these findings of somewhat higher socioeconomic vulnerability relative to the state average are specific to the case-patients' *C. auris* status or represents individuals with healthcare contact.

For methicillin-resistant Staphylococcus aureus (MRSA), neighborhood characteristics such as poverty, lack of education, and access to health care at the census tract level are associated with racial disparities in MRSA infections.[15] Neighborhood deprivation and socioeconomic disadvantage have also previously been linked to increased risk of readmission and frequent contact with healthcare facilities which are risk factors for *C. auris*.[16]

Prior research has shown that individual-level patient characteristics, such as membership in marginalized groups that experience structural racism and ageism, contributed to poor health outcomes during the COVID-19 pandemic in SNFs.[17] More research needs to be done to understand the role of individual risk factors in addition to the neighborhood risk factors that may contribute to multidrug-resistant organism (MDRO) transmission.

When evaluating socioeconomic vulnerability at the facility-level, we found that one-third of all SNFs were in areas with severe disadvantages. In addition, SNFs in neighborhoods with lower socioeconomic status and high numbers of racial minorities were more likely to experience *C. auris* transmission. Prior research shows that SNFs in socioeconomically disadvantaged neighborhoods have less staff, lower quality ratings, and more financial strain.[8,18,19] Future research should clarify the relationship between SNF neighborhood socioeconomic disadvantages and differential environmental exposure or built environment that could contribute to MDRO outbreaks and infection control deficiencies.

Our findings on the clinical characteristics of *C. auris* case-patients are similar to those from previous studies that showed most patients infected or colonized with *C. auris* had multiple comorbidities.[4,20] Particularly, patients were noted to require ventilation, central lines, wound care, and feeding tubes. Many also had extensive prior contact with healthcare facilities which has been shown to be a risk factor for infection.[2,21] Almost half of Maryland case-patients were directly associated with SNFs. Additionally, *C. auris* outbreaks disproportionately occurred in SNFs with ventilator-capable units and infection control practices in SNFs with outbreaks had notable deficiencies. Prior research has highlighted the role that long-term care facilities have played in driving transmission in group settings, particularly in ventilator-capable SNFs.[22]

ICARs were completed at multiple SNFs with ongoing transmission of *C. auris,* and common themes emerged. Poor hand hygiene adherence was noted at multiple SNFs and audits were not routinely performed by infection control staff.

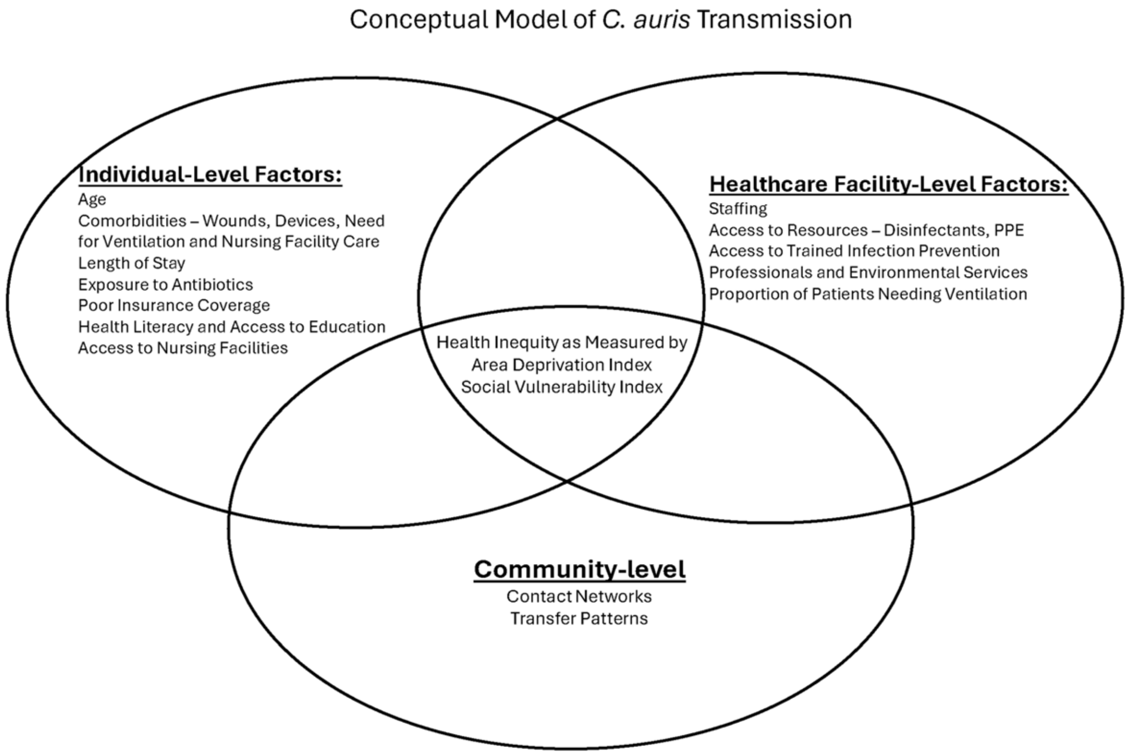

Figure 1. Conceptual model of *C. auris* transmission.

Many SNFs were not using appropriate disinfectants for *C. auris,* noting that there was inconsistent access to cleaning supplies throughout the SNF. Staff including environmental services were not always aware of correct cleaning processes and infection control policies. These observations are consistent with prior infection control assessments during *C. auris* outbreaks and further support the role that strong IPC practices serve in preventing and stopping the spread of infection.[5,23,24]

We observed that many patients in this study had wounds that required wound care. Prior studies have noted that a substantial proportion of *C. auris* case-patients had documented wounds.[5,22] This prompted attention to wound care practices during infection control observations conducted by the MDH IPC team, and lapses in proper infection control during delivery of wound care were observed frequently. Although the relative contribution of risk of colonization due to the presence of wounds and the risk of transmission due to infection control lapses during provision of wound care remains unclear, these findings are consistent with previous studies on other MDROs and suggest the need for focused attention to wound presence and care.[25,26]

This study has several notable limitations. Although we found high comorbidity and higher than expected socioeconomic vulnerability relative to the state average in *C. auris* case-patients, we did not compare individuals with *C. auris* to a control group without *C. auris*. Further, this cohort does not include all case-patients occurring during the period under review; it is likely that additional case-patients of *C. auris* went undetected due to limitations in existing laboratory or epidemiological methods, and while MDH used an aggressive approach to case-patient finding during this period, this also led to surveillance bias toward increased detection in SNFs with initial case-patients. Despite these limitations, we believe that these data suggest a complex interplay between individual- and facility-level neighborhood vulnerability due to both socioeconomic and medical characteristics (Figure 1). Medical conditions that are risk factors for acquisition of *C. auris* or other MDROs may be more prevalent in individuals who are marginalized; these individuals may be more likely to be residents of SNFs that are less able to halt the spread of emerging pathogens due to inadequate resources. Therefore, although infection control opportunities can be identified and addressed in real time in response to transmission and outbreaks, these responses may be short-lived and inadequate. That similar risk factors exist for both risk of infection and MDRO transmission across time and geographic regions suggests that unless underlying systemic factors are addressed, we are likely to see limited success in control of these organisms and to see a replacement of one organism with another in the same vulnerable groups. A longer-term approach to preventing infectious disease transmission and emergence will require policy solutions based on a critical evaluation of underlying socioeconomic vulnerability and targeted, commensurate allocation of resources.

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