CONCISE COMMUNICATION

Residential Proximity to Large Numbers of Swine in Feeding Operations Is Associated with Increased Risk of Methicillin-Resistant *Staphylococcus aureus* Colonization at Time of Hospital Admission in Rural Iowa Veterans

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Among 1,036 patients, residential proximity within 1 mile of large swine facilities was associated with nearly double the risk of methicillin-resistant *Staphylococcus aureus* (MRSA) colonization at admission (relative risk, 1.8786 [95% confidence interval, 1.0928–3.2289]; $P = .0239$) and, after controlling for multiple admissions and age, was associated with nearly triple the odds of MRSA colonization (odds ratio, 2.76 [95% confidence interval, 1.2728–5.9875]; $P = .0101$).

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Methicillin-resistant *Staphylococcus aureus* (MRSA) has been found to colonize both livestock and livestock workers and to transiently colonize visitors to livestock facilities.[1-3] MRSA-colonized livestock can act as reservoirs for the bacterium and transmit MRSA to humans.[4] Thus, there exists potential for the introduction of MRSA into hospitals from livestock via individuals who have close proximity to colonized animals. Livestock density in Dutch administrative areas was a risk factor for livestock-associated MRSA colonization in in-dividuals not engaged in livestock production.[5] Furthermore, residential proximity to farms that used swine manure was found to be associated with MRSA infection in Pennsylvania.[6]

Colonization with MRSA at time of hospital admission is known to increase the risk of MRSA infection and is associated with the introduction of MRSA into healthcare settings.[7] In 2006, the Veterans Administration (VA) implemented a set of procedures, including mandatory admission nares screening, designed to halt the transfer of MRSA into and within hospitals.[8]

There are typically 19 million pigs being raised in Iowa, housed primarily in 7,000 concentrated animal feeding operations (CAFOs). Given these conditions, we examined whether residential proximity to swine CAFOs was associated with increased risk of MRSA-positive nares screening results at the time of admission to the Iowa City Veterans Affairs Health Care System (IC-VAHCS) in rural veterans.

METHODS

Between December 1, 2009, and December 31, 2011, 2,996 patients with an Iowa home address were admitted to the IC-VAHCS. For each patient, the nasal MRSA status at admission, age, and sex were recorded. VA methodology for nares screening and assessment of MRSA colonization status have been described elsewhere.[8]

Patient addresses were geocoded, and then household locations were categorized on the basis of the urban designations of the census. Any veterans whose address could not be geocoded or who lived in urban areas were excluded from further analysis. Data on swine CAFO populations within Iowa were obtained from the Iowa Department of Natural Resources.

TABLE 1. Frequency Table and Relative Risk (RR) Estimates for Methicillin-Resistant *Staphylococcus aureus* (MRSA) Colonization Status by Household Proximity to Swine

Swine AU within 1 mile	No. (%) of patients, by MRSA nares screen result			Unadjusted RR (95% CI)	P^a
	Positive	Negative	Total		
Any vs none				1.4627 (0.909–2.238)	.1239
Any	21 (9.21)	207 (90.79)	228		
None	98 (6.46)	1,420 (93.54)	1,518		
High vs low				1.8786 (1.093–3.229)	.0239
High (>1,000)	13 (12.15)	94 (87.85)	107		
Low (<1,000)	106 (6.47)	1,533 (93.53)	1,639		

NOTE.   Animal units (AUs) are a measure developed by the Iowa Department of Natural Resources to make comparisons between concentrated animal feeding operations raising different species. One fully grown cow equals 1 AU, a mature swine (>55 pounds) equals 0.4 AU, and immature swine are smaller fractions of an AU.
^{a} By χ^2 test.

TABLE 2. Generalized Estimating Equation Regression Estimates for the Effect of Residential Proximity to Swine Concentrated Animal Feeding Operations and Age on Methicillin-Resistant *Staphylococcus aureus* (MRSA)–Positive Nares Screens

Parameter	OR (95% CI) of MRSA-positive nares screen	P
Any swine AU within 1 mile (vs none)	1.6784 (0.8737–3.2240)	.1200
Age, years		
>75	1.8158 (0.9388–3.5122)	.0763
65–75	0.7939 (0.3444–1.8300)	.5880
60–64	0.8693 (0.4086–1.8496)	.7162
<60	...	...
More than 1,000 swine AU within 1 mile (vs <1,000)	2.7606 (1.2728–5.9875)	.0101
Age, years		
>75	1.8206 (0.9453–3.5064)	.0732
65–75	0.7994 (0.6443–1.8560)	.6024
60–64	0.8724 (0.4137–1.8399)	.7200
<60	...	...

NOTE. Animal units (AUs) are a measure developed by the Iowa Department of Natural Resources to make comparisons between concentrated animal feeding operations raising different species. One fully grown cow equals 1 AU, a mature swine (>55 pounds) equals 0.4 AU, and immature swine are smaller fractions of an AU. CI, confidence interval; OR, odds ratio.

Measures of exposure to swine CAFOs were generated for each geocoded patient household. A distance buffer at 1 mile was generated around each patient household in ArcGIS, and the number of swine animal units within this buffer was summed. Two dichotomous variables were generated: no swine within 1 mile of veteran household versus any swine animal units within 1 mile, and low exposure (less than 1,000 swine animal units within 1 mile) versus high exposure (greater than 1,000 swine animal units within 1 mile). The threshold of 1,000 swine animal units was chosen on the basis of Environmental Protection Agency regulations that define a large CAFO as one with 2,500 or greater swine weighing more than 55 pounds (ie, 1,000 swine animal units).

Unadjusted relative risks for MRSA status at time of admission by none or any swine exposure and MRSA status by high or low swine exposure within 1 mile of household were calculated. Because some patients were admitted and screened multiple times, logistic generalized estimating equations (GEEs) with robust standard errors were used to accommodate the dependence between multiple observations per patient.[9] Models also controlled for age and evaluated alternative specifications of age (continuous, polynomial, and categorical). Final results of the GEE models are presented on the basis of categorical age distinctions because of a nonlinear relationship between age and MRSA and the ease of interpretation compared with other specifications. Statistical analyses were completed in SAS, version 9.2 (SAS), and maps were generated using ArcGIS 10.

RESULTS

Of the 1,198 rural veteran patients admitted during the study period, 162 had addresses that could not be geocoded. MRSA colonization positivity among these patients was 6.6% (18 of 271 patients had positive results). The final analytic data set consisted of 1,746 admission nares screening samples obtained from 1,036 unique rural veteran patients. A total of 119 (6.8%) had results positive for MRSA at hospital admission. The median patient age was 65 years (range, 22–98 years). MRSA colonization status at time of admission exhibited a bimodal distribution of risk, with increased colonization in the oldest (older than 75 years) and the youngest (younger than 60 years) frequency quartiles.

There was no significant difference in the MRSA status at time of admission when veterans were stratified by any exposure versus no exposure to swine animal units within 1 mile of their household (relative risk [RR], 1.4267 [95% confidence interval (CI), 0.909–2.238]; P = .1239; Table 1). However, there was a statistically significant difference in MRSA status by high versus low swine exposure, with the RR of presenting with MRSA-positive screening samples nearly doubling for veterans who had greater than 1,000 swine animal units within 1 mile of their residence (RR, 1.879 [95% CI, 1.093–3.229]; P = .0239).

Age was associated with MRSA colonization, with the highest relative odds of MRSA colonization occurring in patients 76 years of age and older (Table 2). After statistically controlling for multiple admissions and age in the GEE model, high swine exposure was associated with nearly triple the odds of MRSA colonization (odds ratio, 2.761 [95% CI, 1.273–5.988]; P = .0101).

DISCUSSION

Overall MRSA carriage among veterans admitted to the IC-VAHCS was 6.8% among rural patients. The risk of MRSA

colonization at admission nearly tripled, however, for rural veterans whose residence was within 1 mile of large swine CAFOs with more than 2,500 mature swine or greater numbers of immature swine.

Although the exact mechanism by which residential proximity to large swine CAFOs increased risk of MRSA is unknown, it appears that there is potential for drug-resistant strains of *S. aureus* in animals to transmit to people living at close distances. For example, a 55-pound or greater hog can produce upward of 10 gallons of manure a day. Typically, in Iowa, manure is spread on surrounding fields, and MRSA can be aerosolized from this manure to human food or water sources.[6]

We were unable to control for livestock contact on the part of veterans or people living in their households. It is possible that direct contact between veterans or their family members and swine is responsible for this relationship. In Germany, MRSA colonization was observed in individuals living in close proximity to pig and poultry farms who did not have direct occupational contact with animals, although their risk for MRSA colonization increased with farm visits or family contact with animals.[3] Data on veterans presenting with a methicillin-susceptible *S. aureus* strain or a strain with a different drug resistance (eg, tetracycline-resistant *S. aureus*) were unavailable. Also unavailable were data on other factors known to be associated with MRSA carriage, such as socioeconomic status, comorbidities, and other healthcare-related exposures, that could suggest either hospital- or community-acquired MRSA. It is also possible that individuals were colonized with MRSA in sites other than the nose.

Genotypes for colonizing *S. aureus* isolates were unavailable, so we could not assess the presence of known livestock-associated types, such as ST398. However, residential proximity to CAFOs could be risky in ways other than simply direct exposure to preexisting livestock-associated *S. aureus* strains, including via exposure to antibiotic residues via air or water, application of manure containing residues near their homes, or other mechanisms. Furthermore, in North America, strains other than ST398 have been found on swine farms and in live pigs, which suggests that the molecular epidemiology of livestock-associated *S. aureus* may be more complex than that observed in European studies.[1,10]

The increasing populations of swine raised in densely populated CAFOs and exposed to antibiotics presents opportunities for drug-resistant pathogens to be transmitted among human populations. Our study indicates that residential proximity to large numbers of swine in CAFOs in Iowa is associated with increased risk of MRSA colonization.

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