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Environmental Risk Factors for Community-Acquired MRSA

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Key Points

- Community-acquired methicillin-resistant *Staphylococcus aureus* (CA-MRSA) is endemic in North America.
- In contrast to MRSA acquired in hospital settings, CA-MRSA is present in a wide variety of environments including health care settings outside of hospitals and animal care settings, beaches and recreational waters, athletic facilities, spas and saunas.
- The risk of infection from environmental exposure to CA-MRSA is unknown.
- Exposure to contaminated high-touch surfaces or fomites and close contact with other colonized people or animals in these environments may contribute to CA-MRSA transmission and colonization.
- Certain occupations, activities or living situations, and/or marginalized populations may have increased exposure to CA-MRSA in specific environments compared to the general public.
- More stringent cleaning and disinfection practices are recommended to reduce transmission and colonization in environments where individuals may be at greater risk of exposure to CA-MRSA.

Introduction

Staphylococcus aureus (*S. aureus*) is a common bacterium that can colonize several body sites including skin and the upper respiratory tract, usually without symptoms.[1] An estimated 80% of the human population are either permanently (approximately 20-33%) or transiently colonized (approximately 60%) with *S. aureus*.[1,2] However, *S. aureus* does not always live in harmony with its human hosts and can cause both local and systemic infections that may need to be treated with antibiotics.[1] Colonization with *S. aureus* refers to the presence of the bacteria in a host, whereas infection is the clinical manifestation (pain, redness, swelling, and warmth) due to the bacteria.[3] Both colonized (asymptomatic) and infected individuals can transmit the bacterium to others and their surroundings.[4]

The antibiotic methicillin was first used in 1960 to treat staphylococcal infections, and resistance was documented in 1961.[5] Over time, methicillin-resistant *S. aureus* (MRSA) has become more prevalent and a serious public health concern.[6] In 1995, there were 106 MRSA infections and 83 MRSA colonizations detected in 374,027 admissions in sentinel hospitals as part of the Canadian Nosocomial Infection Surveillance Program.[7] In 2009, there were 2,036 infections and 4,610 colonizations in 701,477 admissions detected by the same program with an estimate that approximately one in three new MRSA cases originated in the community.[7] Currently, MRSA infections are treated with antibiotics (e.g., cloxacillin, cephalexin, clindamycin, trimethoprim-sulfamethoxazole, doxycycline, fusidic acid, vancomycin, and linezolid) depending on the strain's susceptibility profile.[8]

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MRSA can be classified into different strains depending on the environmental source of the infection: Hospitals (hospital-acquired MRSA); livestock (livestock-acquired MRSA); and communities (community-acquired MRSA).[9] According to the Writing Group of the Expert Panel of Canadian Infectious Disease, Infection Prevention and Control, and Public Health Specialists, hospital-acquired MRSA is defined as "MRSA strains that circulate and are transmitted to individuals within health care facilities."[10] Community-acquired MRSA refers to "MRSA isolates obtained from individuals in the community who have not had recent exposure to the health care system, or from patients in healthcare facilities in whom the infection was present or incubating at the time of admission."[10]

Community-acquired MRSA can be spread through direct or indirect contact with infected bodily fluids.[2] MRSA can survive for days to months on surfaces.[11] Approximately 2% of the general population carry MRSA, and everyone is susceptible to infection.[2,12] However, those with weakened immune systems may be more susceptible to infection.[13,14] Most CA-MRSA infections are localized and appear as red, pus-filled skin lesions.[12] However, if left untreated CA-MRSA can spread to the cardiorespiratory and skeletal systems causing life-threatening illnesses such as pneumonia, pelvic osteomyelitis, septic thrombophlebitis, and necrotizing fasciitis, and may result in death.[12,15] Although the etiology and treatment of CA-MRSA infections are well understood, the environmental risk factors for CA-MRSA infections are largely unknown.[2] A greater awareness of these risk factors may help to suggest more targeted primary prevention strategies.

Objective

The objective of this evidence review was to determine the environmental risk factors for CA-MRSA by conducting a comprehensive search of the current published and grey literature, and to identify gaps in knowledge and/or policy that can be addressed in the future.

Methodology

An initial literature search was conducted between January 30 and February 4, 2014, using the web-based search engines: PubMed Central and Thomson Reuters Web of Science. Subsequent searches were conducted until March 2, 2014 in order to capture the most current information on CA-MRSA and the associated environmental risk factors. Grey literature was identified using Google Scholar, and by searching the websites of the following agencies: Public Health Agency of Canada; Centers for Disease Control and Prevention; and the World Health Organization.

Citation titles and abstracts were screened for relevance using established inclusion/exclusion criteria. Full-text articles including observational studies and environmental sampling studies were then obtained and screened for relevance using the same criteria. In total, 233 citations were identified and 101 were included. See Appendix A for further methodological information.

Results

Environmental reservoirs and fomites

CA-MRSA has been isolated from a wide variety of different environments including natural marine and fresh water environments such as beaches and parks, but more predominantly, from the built environment. These areas include: wastewater treatment plants; public facilities, libraries, athletic centres, spas, and saunas; public transportation including buses, subway trains, and ambulances; city streets; university campuses; microbiological and computer laboratories; shared dwelling spaces; daycares; prisons; health-care clinics; and veterinary hospitals. Fomites, which are inanimate objects that can transmit infectious agents, include automated teller machines, DVD rental machines, artificial turf grass, and copper alloy coins. Based on the number of identified studies from the literature search, the most common environmental reservoirs of concern were: non-hospital human and animal health-care settings (clinics, ambulances, veterinary hospitals); beaches and recreational water; and athletic centres, spas, and saunas. (See Table 1.)

Environmental risk factors

A common exposure pathway was contact with contaminated high-touch surfaces in an environment facilitating transmission from a colonized or infected animal or person. Examples of several environmental settings include veterinary hospitals, non-hospital healthcare clinics and laboratories, public transportation, emergency services vehicles, athletic centres, and dwellings.

The following three examples illustrate evidence of colonization of individuals to CA-MRSA related to exposure to contaminated high-touch surfaces in the same environment. In 2004, Weese et al. collected environmental samples from a Canadian veterinary teaching hospital and found that 62% of surfaces in stalls housing MRSA-positive horses were contaminated in comparison to only 6.9% of surfaces in stalls housing MRSA-negative horses ($p < 0.001$).[16] Commonly used diagnostic and horse equipment, and a clinician's mobile phone were also contaminated. The clinician was later determined to be MRSA-colonized, although no comparison between the particular strains were made.[16] In a study of dental clinics at an American university, 21% of dental students were MRSA-colonized (approximately 10 times greater than the general population), and dental chairs and floors were contaminated, albeit by different strains.[17] In a study of collegiate athletes, 31% and 10% of environmental samples from football and wrestling rooms were contaminated including benches, chalk trays, hand dryers, and door handles.[18] Of the tested athletes, 10% of football players (n=70) and 4% of wrestlers (n=25) were MRSA-positive, whereas none of the non-athletes were colonized (n=50) ($p < 0.05$). These athletes were more likely to share personal items such as water bottles, towels, soap and deodorant compared to non-athletes ($p < 0.05$).[18] On the other hand, a small study by Ryan et al. found that gym surfaces from a university, high school, and private gym were not contaminated with MRSA.[19]

Additional environmental factors implicated in CA-MRSA colonization or infection are summarized according to environmental setting in Table 1.

Table 1. Environmental risk factors for CA-MRSA by setting as determined by environmental setting

Setting	Environmental Risk Factors
Natural Environment	
Beaches[20-29]	• Beachgoer density
Recreational water[30-35]	• High salinity • Lower temperature (i.e., 13°C versus 20°C)[25] • Moderate/temperate seawater supports highest concentration of MRSA followed by tropical/subtropical water and natural/fresh water
Wastewater[36-39]	• Water treatment process • Use of unchlorinated or reclaimed wastewater for agricultural and other purposes
Built Environment	
Ambulances[40-45]	• MRSA-colonized or infected patients • Surfaces in direct contact with patients (headrests, restraints)
Athletic centres[18,19,46-55]	• Multi-user equipment • High-contact surfaces • Skin-to-skin contact sports • Locker rooms and training areas • Carpeted areas have the highest level of contamination versus concrete and tile

Setting	Environmental Risk Factors
Built Environment	
Clinics[17,56-63] • Dental • Ophthalmology • Chiropractic • Pediatric	• High-touch surfaces • Direct contact with patients • Dental health professionals' and dental students' cell phones • Contaminated surfaces • Stethoscopes • Patient treatment tables
Fire services[64-66]	• Living and garage areas
Homeless shelters[67,68]	• Crowded living conditions • Limited access to hygiene facilities • Lack of social support • Behavioural variables: Recent antibiotic use; history of alcoholism or illicit drug use; current smoking status; poor hygiene
Households[69-79]	• Washroom and kitchen surfaces • Surface properties (material absorbency and porosity) • Presence of bodily fluids • Relative humidity • Contaminated retail meat • Bioaerosols • Infected household member • Sharing objects (toys, linens) between family members
Laboratory[80,81]	• High-touch surfaces • Laboratory technicians' hands • Colonized employees
Prisons[67,82-84]	• Incarceration and its associated environmental, social and behavioural risk factors • Prison washrooms • Health services area • Inmate housing
Public fomites[29,33,85-92] Razors, plastic toys, ceramics, soap, wood, vinyl, towels, bed sheets, shoulder pads, DVDs, ATMs, computer screens, coins, computer keyboards, water fountains, furniture, TV remotes, bathroom surfaces, washing machines, locker handles, elevator buttons, artificial turf grass, canine feces, floors	• High-touch, community access objects • Number of different users • Frequency of use

Setting	Environmental Risk Factors
Built Environment	
Public transportation[93-99]	High-touch surfaces such as passenger handrails and straps High daily ridership Cloth seats are more likely to be contaminated versus vinyl seats and metal seats
University campuses[29,87,100-103]	• High-touch surfaces on ATMs, computer keyboards and floors, and in washrooms • Communal computers in libraries and computer labs • Multi-student dwellings (particularly athletes' dormitories) • Washrooms, furniture, TV remotes, and washing machines in student dwellings
Veterinary hospital[16,104-106]	Animal and human high touch surfaces • MRSA-positive animals

Populations at risk

Studies identified specific populations at risk based on their behaviour or interaction with some of these environments. These included occupational groups such as veterinarians and emergency response workers, as well as population groups in public and private community facilities such as beach-goers; athletes; households, particularly those with children; and marginalized populations. Marginalized populations include Aboriginals and people who are homeless, use illicit drugs, or are imprisoned. Having an open wound or skin lesion was a common risk factor for beach-goers and athletes. Sharing personal items was an identified risk factor for athletes; household members; and people who use drugs. Working or living with pets was common for veterinarians and many households. The following examples further illustrate possible environmental reservoirs and colonization to CA-MRSA in a selection of these populations.

Emergency response workers are likely to having close personal contact with bodily fluids or to contaminated surfaces. In a German study in 2011, 9% of ambulances were contaminated after transport of an MRSA-positive individual with transportation time (1-10 minutes versus 11-20 minutes) having no effect on contamination (p >0.05).[43] Similar studies determined that at least one sampled site in 8-49% of ambulances were MRSA-positive suggesting that emergency response workers may be at increased risk of occupational exposure to MRSA.[40-42,45]

Among marginalized populations, a high proportion of the homeless was found to have exposure to MRSA. For example, a 2009 study in Ohio found that 25.6% of homeless individuals tested at three shelters and an outreach event were colonized by MRSA.[68] Incarcerated individuals are also at risk for CA-MRSA; in a Texas jail, 6.1% of sampled surfaces including seats, toilet buttons and seats, bathroom faucet buttons, stair railings, and table tops were contaminated by MRSA.[83]

The household is recognized as a community reservoir for *S.aureus*. In a case-control study, swabs were cultured for *S.aureus* from samples taken from all household members and selected environmental household items (fomites) involving 146 CA-MRSA positive cases and 145 controls.[78] Case household environments were 9.8 times more likely to be contaminated with MRSA (95% CI: 4.0-24.0, p <0.01). Environmental contamination with a colonizing or clinical infection strain (aOR 5.4 (2.9-10.3) and the presence of a child under 5 (aOR 2.3, 05% CI 1.2-4.5) were each associated with transmission.[78] In another case-control study, 95 cases and 95 controls were enrolled to determine any associations between risk factors and MRSA infection.[79] Cases were 6.8 times more likely to have at least one household surface contaminated with MRSA compared to controls (95% CI: 2.4-19.4, p <0.001).[79]

Table 2 summarizes known personal and environmental risk factors according to occupational and community population groups.

Table 2. Population groups and their risk factors for CA-MRSA colonization

Population	Risk Factors
Individuals whose occupation involves working with animals or their carcasses[107,108] • Veterinarians • Farmers	Contact with live animals Working in the barn Living on or near a farm Occupational exposure via environmental contamination Certain livestock or production species
Beach goers	Digging or being buried in the sand Skin lesions/open wounds Young children, elderly, immunocompromised
Athletes[48,51] • High school • College • Professional	Skin trauma from turf burns and shaving Open wounds Sharing of unwashed bath towels, balms, and lubricants
Households[69,70,78,109]	Presence of a young child (<5 years) Pet ownership Sharing items such as linens and toys between family members
Marginalized populations[68,110] • Homeless • People who use illicit drugs • Men who have sex with men • Prison inmates	Ethnicity Gender Age Household size HIV status Crowded living conditions Lack of access to hygiene facilities Recent antibiotic use History of alcoholism or illicit drug use Current smoking status Poor hygiene Using drugs and sharing contaminated drug paraphernalia Low-income urban areas
Other[111,112]	Sharing scuba diving equipment Receiving a tattoo from an unlicensed artist using homemade equipment in public spaces (such as parks)

Discussion

Given the potential susceptibility for acquiring a CA-MRSA infection, it is important to understand the environments and their risk factors that enable CA-MRSA transmission. We have identified diverse environmental settings and their implicated risk factors for CA-MRSA infection. Although some reservoirs were in natural environments, the majority were in specific built environments such as athletic centres where opportunities for exposure may be more frequent.[18,49,54] High-touch surfaces and opportunity for close contact with an infected person or animal were commonly identified as risk factors for CA-MRSA colonization or infection in a number of different environments. We also identified certain populations that may be at greater risk of exposure given their interaction with these environments. These included athletes, marginalized populations, and certain occupations such as veterinarians and emergency response workers.

It is important to note that the pathways between environmental exposure and infection have not been clearly established.[2] However, the interaction of CA-MRSA, a susceptible population, and the environment may be modelled as an epidemiological triad in order to explain current disease trends. The epidemiological triad is one of several models of causation that suggests that the interaction between the host, agent, and the environment contributes to disease.[113] Altering at least one of these three elements changes the disease process. For example, routine sanitization of high-touch surfaces would change the environment and possibly reduce the risk of CA-MRSA infection even though CA-MRSA virulence and human susceptibility have not changed. Understanding and considering the interactions between CA-MRSA, the population, and the environment may help develop a preventive approach.

Public health responses should consider the specific populations that interact within these environments, what messaging is required to prevent contamination of these areas, and how to effectively communicate risk and preventive strategies to them. Given the common presence of CA-MRSA, it is important for the general public to be aware of where they may be at greater risk of infection and to employ practical and effective primary prevention strategies. Current prevention strategies include good hygienic practices and avoiding contact with others' personal items in public settings. Another possible prevention strategy is to include increasing signage in athletic recreation centres, spas, and saunas to educate users of the potential for CA-MRSA contamination. Specific populations-at-risk can be targeted. For example, student health services at universities could educate students, staff, and faculty about potential public fomites on campus. However, it is important that public messages are written using non-alarmist language in order to prevent increased anxiety or avoidance of sport facilities and other environments. Other public health responses may include more proactive measures such as increased sanitization of passenger handrails on public transit, or increased public health inspection of identified reservoirs and fomites for the presence of CA-MRSA.

Further understanding of the prevalence of CA-MRSA and risk of infection due to environmental exposure would more fully characterize the public health implications for this and perhaps other antibiotic-resistant pathogens.

Limitations

The generalizability of this evidence review is limited by a number of factors including:

- Inclusion of small observational studies: The results of this evidence review were primarily gathered from small observational studies conducted outside of Canada. Well-designed, larger-scale studies and/or systematic reviews and meta-analysis are needed to strengthen these findings and increase the reliability of our conclusions in the Canadian context;
- Potential for bias: This review was limited to studies written in English. Six citations (2.6% of 233 identified citations) were unable to be retrieved. The exclusion of other studies may have biased our results. As in most reviews, there is the potential for publication bias, where publication favors positive results;
- Differences between studies: Use of different sampling techniques and laboratory culturing methods may have influenced the sensitivity and specificity of CA-MRSA detection. Some experimental studies may not be representative of real-world conditions.

Gaps in the Literature

Based on our review of the evidence, there are important gaps that must be addressed. These include:

- Understanding the epidemiological triad of CA-MRSA as it relates to the environment and humans. In particular, future research is needed to explore the role of the environment in CA-MRSA transmission and colonization;
- Estimating the burden of MRSA infections that are due to environmental exposure in specific communities including Canadian Aboriginal peoples;
- Identifying further environmental exposures and their associated risks through observational studies and risk assessments;
- Estimating the current level of awareness of higher risk environments for CA-MRSA, and effective prevention strategies for the general public;
- Understanding the potential impact of variability in environmental sampling and laboratory culturing techniques or conditions on MRSA isolation and prevalence estimates;
- Developing appropriate and effective risk communication strategies to prevent CA-MRSA infections in the population.

Conclusion

CA-MRSA is present in natural environments and a wide variety of built environments including athletic centers, veterinary hospitals, and homeless shelters. Contact with high-touch surfaces such as ATMs, computer keyboards, and other fomite surfaces, as well as transmission from infected or colonized persons or animals, may increase the risk of exposure in these environments. Certain populations such as emergency response workers and marginalized populations may be at greater risk of exposure given their interaction with these environments. However, the links between environmental exposure, transmission, colonization, and infection remain unknown.

Planning and delivering public health initiatives that incorporate these environmental and population risk factors may improve general awareness and implementation of good hygienic practices aimed at preventing exposure to CA-MRSA.

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Appendix A – Methodology

A.1 Databases and Search Terms

The web-based search engines PubMed Central and Thomson Reuters Web of Science were used to identify relevant formal literature. The search terms and combinations that were used include: community-acquired infection(s); community setting; community-acquired methicillin-resistant *Staphylococcus aureus*; Methicillin-resistant *Staphylococcus aureus*; MRSA; resistant *Staphylococcus aureus*; microbe survival; disease transmission, infectious; disease reservoirs; fomites; risk; risk factor; environment and public health; surfaces; public surfaces; surface hygiene; reservoir; environmental microbiology; environmental contamination; environmental hygiene; equipment contamination; household articles; and, family characteristics.

A.2 Inclusion/Exclusion Protocol

Inclusion criteria were of relevance to environmental sources of or exposures to MRSA (or *S. aureus*); written in English; and were accessible by the University of Guelph or National Collaborating Centre for Environmental Health. Exclusion criteria were relevance to hospital-acquired or livestock-acquired MRSA; long-term care facilities or nursing home settings; case reports; case studies; or review articles. In total, 233 citations were identified and 101 were included.

A.3 Data Management

Citations were managed using Microsoft Excel. References were imported and managed in RefWorks (www.refworks.com) and EndNote (www.myendnoteweb.com).

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