Meticillin-resistant *Staphylococcus aureus* among US prisoners and military personnel: review and recommendations for future studies

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We reviewed published work examining the prevalence and risk factors for meticillin-resistant *Staphylococcus aureus* (MRSA) infection in two high-risk groups: prisoners and military enlistees. Significant risk factors for infection included prison occupation, gender, comorbidities, prior skin infection, and previous antibiotic use. Although characteristics such as hygiene, physical contact, and crowding were postulated as risk factors for MRSA infection, there were few epidemiological studies supporting these factors. Most studies identified were retrospective in design and only one study used prospective surveillance for MRSA colonisation among all individuals residing within a single military setting. Our results suggest that there is a high incidence of MRSA infection among individuals in prisons and military settings, but surveys that quantify the prevalence of MRSA colonisation among individuals living within these specialised settings are needed. A thorough examination of MRSA acquisition and transmission patterns in prisons and military settings could help elucidate preventive strategies in other crowded and closed settings.

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Introduction

In the 1990s a change in the epidemiology of meticillin-resistant *Staphylococcus aureus* (MRSA) was noted when serious, sometimes even fatal infections began to occur among healthy members of the community without the traditional risk factors associated with exposure to the hospital setting.[1–4] MRSA has now been reported among healthy children, urban poor/homeless, military personnel, prisoners, injection drug users, institutionalised adults with developmental disabilities, and members of athletic teams.[1–3,5–9] Using a population-based survey in Baltimore, MD, USA and Atlanta, GA, USA, together with a hospital laboratory-based survey in 12 Minnesota hospitals, Fridkin and colleagues[10] estimated that 8–20% of MRSA was community acquired, and that 6% of these cases were invasive.

Community-associated MRSA differs in several ways from health-care-associated infections. Community-associated MRSA is not associated with known risk factors—eg, comorbidities and long-term antibiotic use—and is several times more likely than health-care-associated strains to cause skin and soft tissues infections.[11–13] Many community-associated MRSA strains differ from hospital-associated strains in their mobile genetic element, carrying staphylococcal chromosomal cassette *mec* (SCC*mec*) type IV.[14] This genotype is often less resistant to non-beta-lactam antibiotics,[14–17] but more likely to carry Panton-Valentine leukocidin (PVL), a virulence factor that may be responsible for the increased morbidity and mortality associated with community-associated MRSA infections.[18,19] Characteristics that are often used to distinguish health-care-associated MRSA and community-associated MRSA are summarised in table 1.

An examination of the patterns of acquisition and transmission of resistant strains in crowded and closed settings could help to elucidate preventive strategies while new therapeutic agents are being developed. We review research that has been done to examine the prevalence and transmission dynamics of MRSA in two high-risk groups in the community setting: incarcerated populations and military recruits. These two populations share important demographic and environmental characteristics, including similar age distributions, crowded living conditions, and other potential physical and hygiene risk factors.

MRSA among incarcerated individuals

Our search yielded 11 articles, of which seven studies assessed MRSA among incarcerated populations (table 2). Four of the articles were based on outbreak investigations. Five of the studies were done in state prison populations and two were done among jailed populations. Three studies examined the prevalence of MRSA from clinically identified infections among incarcerated patients. The prevalence of MRSA among *S aureus* isolates collected from incarcerated patients in the San Francisco County Jail system increased from 29% in 1997 to 74% in 2002 ($p<0·0001$).[30] Most of the isolates carried SCC*mec* type IV, commonly associated with community-associated MRSA.[30] In Texas jails and prisons, the proportion of

Characteristic	Health-care-associated MRSA	Community-associated MRSA
Associated with frequent or longer-term antibiotic use and medical comorbidities	Yes	No
Associated with health-care exposure in the past year	Yes	Yes
Usually causes skin and soft tissue infections and pneumonia	No	Yes
Resistant to beta-lactam antibiotics	Yes	Yes
Resistant to clindamycin and fluoroquinolones	Yes	Yes/No
SCC*mec*		
Types I–III	Yes	No
Types IV and V	No	Yes
Panton-Valentine leukocidin	No	Yes

Table 1: **Characteristics of health-care-associated and community-associated MRSA**[10,15,20–24]

MRSA among prison patients with *S aureus* infections increased from 25% (864/3520) in 1998 to 66% (5684/8633) in 2002.[28] A high proportion of MRSA isolated from jail inmates in San Francisco carried the genes for PVL,[20] indicating that these isolates are likely to be more virulent community-associated strains.

A number of risk factors were implicated in outbreaks of MRSA among inmates in correctional facilities in Georgia, California, and Texas (table 2). These risk factors included commonly identified characteristics such as comorbidities and history of antimicrobial use, as well as factors associated with crowding and inadequate hygiene. In one study of an MRSA outbreak in a Mississippi prison, investigators reported that significantly more women were colonised with MRSA compared with men (73/1241 [5·9%] *vs* 13/516 [2·5%]; p=0·003).[26] Similarly, a prevalence study of clinical isolates in a Texas prison identified a slightly higher prevalence of MRSA infection among women compared with men.[27] Reasons for the observed sex differences were not discussed in either study.

Most MRSA isolates tested were susceptible to all antimicrobial agents except for beta-lactam antibiotics and erythromycin. In addition, clones identified by pulsed field gel electrophoresis (PFGE) from outbreak isolates were predominantly indistinguishable, suggesting person-to-person transmission within the correctional facilities.

MRSA among individuals associated with military

Our search yielded 18 different articles on MRSA and the military; our inclusion criteria limited these references to eight studies within military populations and military clinical settings (table 3). Similar to the prison studies, three studies were associated with outbreak investigations. The locations included military training facilities, military hospitals/clinics, and a naval ship. In five studies, the prevalence of MRSA or community-associated MRSA among military populations was examined, and four of these studies were done within military medical facilities. A survey for staphylococcal carriage was done in one outbreak investigation among military trainees.[8] Of 206 trainees surveyed, 22 (10·7%) had symptoms of clinical infection and four (1·9%) were colonised with MRSA.[8] In a prospective study of community-associated MRSA colonisation of the nares among recruits at a training facility, the prevalence of carriage among recruits was 3% at baseline and these colonised recruits were significantly more likely to experience skin or soft tissue infections over the 8–10 week training period compared with recruits colonised with meticillin-susceptible *S aureus* (MSSA; p<0·001).[37] All nine strains associated with clinical infections among these recruits were PVL positive and eight of these nine strains appeared to have a PFGE pattern that was similar to type USA300.[37] In a retrospective chart review of outpatients visiting a military hospital, the prevalence of MSSA and MRSA colonisation among asymptomatic individuals was 38% and 2%, respectively.[34]

Risk factors were less well characterised in military population studies compared with the prison reports. The commonly identified risk factors for MRSA infection in military populations included comorbidities such as cystic fibrosis or diabetes, history of antimicrobial use, contact with an MRSA patient, and health-care occupation. In addition to these common risk factors across studies, Campbell and colleagues[8] reported that the presence of a training roommate with a prior skin infection was an important risk factor for subsequent MRSA infection. In this same study, all staphylococcal

Reference	Study design	Study population and location	Number of people	Prevalence/risk factors and effect estimates or significance level
Wootton et al[25]	Outbreak investigation/ case-control	Prisoners in a Georgia correctional facility	Seven cases and 19 controls	Dormitory orderly work (OR 9·8, 95%CI 0·74–6·38) Stay of longer than 36 days (OR 6·9, 95%CI 0·65–1·28) Self-lancing of boil (OR 4·4, p=0·36)
Anon[26]	Outbreak investigation/ MRSA carriage study	State prisoners in Mississippi	1757	86 (4·9%) inmates sampled were colonised with MRSA Women were more likely to be colonised than men (p=0·003) Individuals incarcerated for more than 60 days were more likely to be colonised compared with those incarcerated for 60 days or less (p=0·01)
Baillargeon et al[27]	Cohort of clinical infections	Patient medical record review in Texas prisons	299 179	12 MRSA infections per 1000 person-years Several comorbidities—eg, HIV/AIDS and liver disease—were significant risk factors for MRSA infection (all p<0·05)
Baillargeon et al[28]	Prevalence of clinical infections	Prison patient medical record review from Texas prisons	336 668	327·9 MRSA infections per 100 000 inmates
Anon[29]	Outbreak investigation dispatch	Prisoners in Los Angeles county jail	66	..
Pan et al[30]	Retrospective prevalence	Jail patient medical record review from San Francisco jails	295	153 (54%) *S aureus* isolates over a 6-year period were MRSA positive Prevalence of *S aureus* infection increased from 29% in 1997 to 74% in 2002 (p<0·0001)
Anon[31]	Outbreak investigations/ case-control	Prisoners in Georgia, California, and Texas prison systems*	..	864/3520 (25%) of *S aureus* cultures were MRSA positive in 1998; 5684/8633 (66%) of *S aureus* cultures were MRSA positive in 2002. Numerous risk factors postulated but no statistical significance testing to estimate association with MRSA infection

..=not reported. *Data on prevalence only available in Texas facilities.

Table 2: **Risk factors, typing methods, and results for MRSA among incarcerated people**

Reference	Study design	Study population and location	Number of people	Prevalence and risk factors
Kallen et al[32]	Prevalence using retrospective chart review*	Patients at a Naval medical centre	..	13/43 (30%) of community-associated MRSA isolates identified from 1994–95 compared with 45/91 (49%) from 1996–97 (p=0·04)
Baum et al[33]	Prevalence using retrospective review of medical records*	Patients at an Army medical centre	67	24 (36%) MRSA isolates were identified as community-associated MRSA
Kenner et al[34]	Prospective prevalence	Outpatients at military clinics	404	153 (38%) of asymptomatic outpatients were colonised with MSSA and 8 (2%) were colonised with MRSA. No statistically significant risk factors for MRSA colonisation were identified
LaMar et al[35]	Descriptive outbreak investigation of MRSA among naval officers	Marines/US Navy ship	125	8 (6·4%) of marines were MRSA infected or colonised
Campbell et al[8]	Outbreak investigation	Military recruits at a training facility	206	22 (10·7%) were MRSA infected and 4 (1·9%) were MRSA colonised. Risk factors included having a roommate with a prior skin infection (OR 3·44, 95% CI 1·34–8·85) and a family member or friend in health-care occupation (OR 2·79, 95% CI 1·09–7·15)
Zinderman et al[36]	Outbreak investigation	Military recruits at a training facility	235	47 MRSA infections from October 2000 to July 2002. Most recruits did not have established risk factors for MRSA but transmission increased with duration of training and field exercises
Ellis et al[37]	Prospective observational study of prevalence and risk factors for community-associated MRSA	Army medic trainees in barracks at a training facility	812	24 (3%) were colonised with community-associated MRSA in the nares and 9 (38%) of those developed soft-tissue infection over the 8–10 week training period. There was a significantly higher risk of developing soft tissue or skin infection among community-associated MRSA colonised versus MSSA colonised (RR 10·7; 95%CI 4·6–25·2). Previous antibiotic use at baseline was a significant risk factor of colonisation (p=0·03)
Beilman et al[38]	Prevalence study using retrospective chart review	Military trainee patients at an Army community hospital	1041	239 (23%) *S aureus* isolates were resistant to meticillin during the period 1998–2003. From 1998–2003 there was a 31% increase in the incidence of MRSA (p<0·001) and a 13% increase in community-associated MRSA (p=0·026)

*These studies reported MRSA prevalence among a mix of military and non-military participants.

***Table 3*: Risk factors, typing methods, and results for MRSA among military people**

isolates from the 22 MRSA-infected military recruits were positive for *mecA* (a gene carried on SCC*mec* that encodes PBP2a, a penicillin binding protein with reduced affinity for beta-lactam antibiotics that confers meticillin resistance to *S aureus*), had the PVL gene, and were identified as multilocus sequence type 8.[8] This study suggests that sharing crowded barracks may influence transmission in this military setting. Military outbreak studies postulated that inadequate hygiene and physical trauma associated with recruit training may have influenced the emergence of MRSA infection among trainees, but these studies did not use statistical tests to assess the strength of the association between these factors and the risk of MRSA infection.[8,36]

Similar to the prison study findings, most military MRSA isolates tested were susceptible to all antimicrobial agents except for beta-lactam antibiotics and erythromycin. Five of the studies used molecular strain typing techniques and four of these reported similarities among strain types, indicating clonal transmission among cases (table 3). In one study in which both PFGE and toxin testing were done with community-associated MRSA isolates among recruits at a training facility, most isolates that were community associated (type IVa) carried the PVL gene.[25]

Discussion

The prevalence of multidrug-resistant organisms such as MRSA within US prison and military populations has important implications for the general public given the increases in rates of incarceration and active military duty. The US has the second highest rates of incarceration in the world and each year about 7 million people are processed within the US correctional system.[39] The incarceration rate has increased by more than 300% since 1980[39] and at any given time there are approximately 200 000 inmates in federal prisons.[40] In 2001, almost 600 000 state prison inmates were released into the community and close to 33% of those released had been convicted of drug-related offences.[41] Similarly, the military population has been growing steadily in the past few years. At the end of fiscal year 2002, the number of enlisted forces was close to 1·18 million. The mean number of months in service per enlisted individual was 84 months in 2002.[42]

Recently, Kuehnert and colleagues[43] examined the population-based prevalence of *S aureus* nasal carriage among participants in the US National Health and Nutrition Examination Survey 2001–02. This study estimated the weighted US population average of *S aureus* carriage at 89·4 million and MRSA carriage at 2·3 million.[37] Two important risk factors for community-associated MRSA carriage were identified in this population-based study—young age and non-Hispanic black ethnicity.[43] In addition to risk factors for carriage of MRSA, factors that may enhance risk of infection in the community setting include living or working in crowded conditions, skin diseases, and immunosuppression.[21,44] Hence, the combination of demographic and environmental conditions that may characterise the prison or military recruit settings can magnify risk for both colonisation and subsequent infection with MRSA.

Although several studies in our review have suggested that characteristics such as living and working in crowded environments, physically demanding labour, and training programmes are all important risk factors, few studies

have directly tested whether there is an epidemiological association with these suggested risk factors and community-associated MRSA infection in either prison or military settings. This lack of research is concerning, since a recent survey of handwashing among military training recruits reported that almost half of the recruits cited barriers to washing hands during training, including insufficient time to wash hands, limited number of sinks, and lack of soap.[45]

The situation among incarcerated populations is likely to be even more problematic, since these individuals not only live in close and crowded quarters but also have a higher prevalence of other risk factors such as history of intravenous drug use or concomitant infections such as HIV, hepatitis B or C, and tuberculosis.[28] Moreover, the primary concern in the prison system is security and therefore prison infection control practitioners must operate within a limited range of authority, including restricted use of certain types of soaps and alcohol-based hand sanitisers. For these reasons, prison populations are more likely to be affected by both community-associated and health-care-associated strains and other multidrug-resistant organisms.

Before incarceration and after release from prison, prisoners may serve as an important reservoir of resistant organisms that can then be transmitted to the community. For example, 89% of residents in a New York City long-term drug rehabilitation facility for patients with AIDS had been previously imprisoned, and there was a sustained high rate of closely linked strains of MRSA within that group.[22] Similarly, dissemination of MRSA infection to other family members or within the surrounding community may occur after military recruits return from training or active duty. However, there are few research studies that have been designed to track the transmission pathways emanating from MRSA in the prison or military setting directly to infections occurring among individuals in the community. Pan and co-workers[30] suggested a link between community-associated MRSA isolates obtained from jailed patients and circulation of these strains in the community setting. They reported that four of the six major multilocus sequence typing clonal groups identified among jailed patients belonged to three of five globally epidemic MRSA clonal groups (CC30, CC8, and CC5).[30] Hence, clones identified within this incarcerated population appear to have been derived from clones circulating within the global community setting.

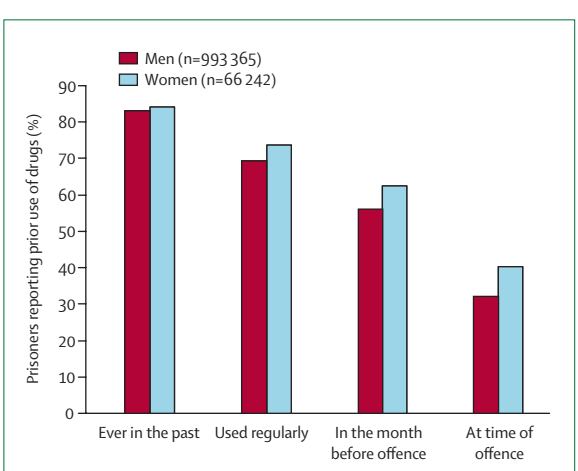

Figure: **Prior drug abuse by gender among state prisoners in 1997**[48]

Although molecular typing methods have been used in both military and prison studies, none of the studies assessed here linked demographic and risk factor information with results from molecular typing. Results from molecular epidemiological tests may suggest relations between strains, but without knowledge of demographic, social, and risk factor information, it is difficult to fully characterise the underlying transmission dynamics of MRSA.[46] Therefore, further research combining molecular typing of *S aureus* isolates and risk factor data among prison and military populations is needed.

Recommendations and new directions

Jails, prisons, and military settings represent a model of the transmission dynamics of drug-resistant organisms—eg, MRSA—that are spread primarily by person-to-person contact. Epidemiological, molecular, and sociological information obtained from MRSA studies among incarcerated people and the military will be useful in preventing transmission not only among these two specialised populations, but also among people in other closed and crowded living conditions. Given that several of the reviewed studies noted a high proportion of MSSA colonisation, research assessing virulence factors other than PVL that could act as risk factors for subsequent MRSA infection within prison and military settings is needed. Such information would provide a better understanding of the microbial factors that are important in transmission and ultimately control within these specialised settings.

Collectively, the available data from prison/jail and military studies suggest that there is a high prevalence of MRSA infection among individuals that receive clinical treatment while in these settings as well as during outbreak investigations. However, as Baillargeon and colleagues[27] point out, a more appropriate disease ascertainment method is to enumerate the entire prison population rather than solely focusing on surveillance data from individuals with clinical disease, since many MRSA infections may go undiagnosed or uncultured. Data from surveys done within prison or military settings would also provide specific estimates of the prevalence of colonisation—an essential precursor to infection. To our knowledge, no prevalence studies of MRSA colonisation have been done among prison populations and we identified only a single military-based prevalence survey among recruits residing within a military setting.[37] This

study reported a relatively high prevalence of MRSA colonisation (3%).[37] Thus, only the tip of the iceberg is known. Such prevalence surveys are needed along with prospective surveillance of risk factors for transmission. Currently, it is not clear if nasal colonisation acts as a reservoir for subsequent infection in these specialised settings or if *S aureus* is primarily transmitted from skin to infected skin.

Colonisation patterns for MRSA among community-dwelling drug users and HIV-infected people have been shown to be closely linked within drug-use networks.[47] Use of drugs is prevalent before incarceration and often occurs close to or during the criminal offence (figure). In 1997, the proportion of state prisoners who admitted to ever injecting non-prescription drugs was 20%; 15% reported using heroin regularly. Lowy and Miller[46] have suggested a framework to investigate the transmission dynamics of infectious diseases such as *S aureus* among drug-using populations. They suggest the integration of molecular epidemiological techniques with social networking methods to elucidate biological, social, and drug-use links associated with transmission, and provide several examples in which these methods were successfully used to identify both sources and locations of disease transmission. This multidisciplinary approach is ideally suited for studies of transmission dynamics within and among incarcerated people (and possibly prison/jail staff members as well) and within closed military settings.

Prevention guidelines and practical interventions

The Federal Bureau of Prisons (BOP) has guidelines for infection control available on its website.[49] The guidelines include general statements regarding training and counselling on prevention, proper waste disposal, and use of universal precautions, as well as some specific mandates (eg, mandatory HIV testing and use of Occupational Safety and Health Administration guidelines for precautions for bloodborne infections). The guidelines also discuss the need for primary prevention, health education, and environmental controls to prevent transmission of infection and states that prisons will adhere to CDC guidelines for infection control. Particular attention is given to HIV/AIDS, hepatitis B, tuberculosis, and sexually transmitted diseases, but no mention is made of multidrug-resistant organisms.

Following several outbreaks of MRSA within correctional facilities,[31] BOP issued clinical practice guidelines for the management of MRSA in October, 2003.[50] These guidelines provide specific references and clear definitions of types of precautions to be taken, plus diagnosis, treatment, and infection control protocols. Recommendations for primary prevention include education of staff and inmates, standard precautions, a hand hygiene programme, environmental sanitation, and screening measures. There are also recommendations for handling outbreaks and reducing secondary transmission. In summary, these guidelines provide state-of-the-science information and represents a major advance in standard setting for prevention of contact-spread infections in prisons.

As a consequence of MRSA outbreaks within the Texas prison population, new guidelines for treatment and prevention have been added to the Texas Department of Criminal Justice. Similar to the guidelines recently drafted by the BOP, the control measures include surveillance for infected lesions, hygiene education for inmates, proper wound care, antibiotic therapy based on susceptibility, early treatment of skin disease, and eradication of MRSA from asymptomatic carriers who have recurrent MRSA infection. However, implementation of the guidelines in the Texas prison population did not lead to substantial decreases in the reported incidence of MRSA.[31] A more formal intervention trial in a Georgia correctional facility resulted in a reduction in MRSA rates from 11·6 infections to 0 infections per 10 000 inmate days (p=0.003).[25] Measures implemented included improved screening for skin disease, personal hygiene, wound care, and antimicrobial therapy. It is likely that simple, sustainable, and cost-effective measures can indeed have a positive impact on the acquisition and transmission of MRSA within prison settings.

In 2005 the US Navy Environmental Health Center released guidelines for the prevention, treatment, and containment of community-associated MRSA infection in Naval and Marine Corps personnel.[51] These guidelines outline prevention and management strategies to identify outbreaks within operational units and training facilities. The recommendations include maintaining and enforcing good hygiene throughout the day, clean barracks and bathrooms, immediate reporting of localised case clusters, awareness among personnel, surveillance by military health care, treatment with appropriate

Search strategy and selection criteria

We searched PubMed and Medline for articles with a combination of the following keywords: "MRSA", "meticillin-resistant *Staphylococcus aureus*", "military", "army", "navy", "marines", "prison", "jail", and "incarceration". No limits were used for the date of publication. Additional papers were obtained by searching the reference lists in the retrieved papers. Articles were restricted to those written in English, done among incarcerated populations in US prisons or jails, and among populations in military settings or on active duty. For military articles, we excluded studies that were done in military hospitals or clinics that only reported results of MRSA infection among civilian (ie, non-military) patients attending a military hospital or clinic. We included studies that assessed a mixture of military and non-military patient populations. Conference abstracts were not included.

antibiotics and wound care as frequently as needed, adequate hygiene and wound care during field training evolutions, and routine cleaning of training gear and equipment. Nevertheless, without data regarding the prevalence of MRSA among military recruits it is difficult to assess the impact that these new guidelines will have on reducing transmission and infection with MRSA in military settings.

Research on multidrug-resistant organisms such as MRSA in prisons and within the military environment should focus on characterising the extent of the problem with prevalence surveillance and using molecular epidemiological and social networking techniques to elucidate the transmission dynamics and nature of the problem. From such studies, targeted, sustainable, and cost-effective interventions can be developed. The excellent practice guidelines disseminated by BOP and the Navy Environmental Health Center need to be implemented and their impact on reducing MRSA transmission tested.

Conflicts of interest

We declare that we have no conflicts of interest.

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