

# Community-Acquired Methicillin-Resistant *Staphylococcus aureus* (CA-MRSA)

## Investigation on a United States Navy Ship

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### Abstract

**Objective:** Investigate colonization and risk factors associated with an outbreak of community-associated methicillin-resistant *Staphylococcus aureus* (CA-MRSA) skin and soft tissue infections (SSTI) on a United States Navy surface ship.

**Methods:** Descriptive survey of outbreak population characteristics and culture-based surveillance of the ship population for colonization with *Staphylococcus aureus*.

**Results:** Eighty-five percent (266/313; 85%) of the crew were included in the study, although all 296 available members consented to surveillance questionnaire and cultures (296/313; 94.6%). Seventy-three (73/266; 27.4%) were colonized with *S. aureus*, 18 of which were MRSA (18/73; 24% and 18/266; 6.8%). Pulsed-field gel electrophoresis (PFGE) revealed all strains were pulsed-field type (PFT) USA 300. Key factors within the past 12 months included antibiotic use (OR=2.88, p=0.036), medical care (OR=3.32, p=0.011), or history of skin problems (OR=2.73, p=0.032).

**Conclusions:** Surveillance indicated a surprising rate of CA-MRSA carriage among sailors assigned to this ship, which was likely associated with the SSTI infections among crew members while previously at sea. Important risk factors in this confined population included recent access to outpatient healthcare services. The PFGE types were USA 300, which is commonly community-associated, and not a healthcare-associated strain by definition.

**Implications:** In addition to its established public health importance in SSTI within civilian communities, this report demonstrates the increasing role of CA-MRSA as an emerging pathogen among military populations. Hawaii's large military population and strategic location underscores the potential impact of drug-resistant staphylococcus infections on military readiness in the Pacific.

### Introduction

Methicillin-resistant *Staphylococcus aureus* (MRSA) represents an emerging pathogen of increasing military and civilian importance.<sup>2,3,4</sup> Among the general U.S. population, the percentage of individuals who carry *Staphylococcus aureus* which are resistant to beta lactamase-resistant penicillins such as methicillin and oxacillin has been reported as 0.2 to 7.3%<sup>5,6,7,8</sup> and has been increasing nationally<sup>9</sup>. Community-associated MRSA (CA-MRSA) strains typically differ from hospital-associated (HA-MRSA) strains in several characteristics, including limited antimicrobial resistance (beta-lactam and macrolide antimicrobics) and possession of *mec* staphylococcal cassette chromosome (*SSCmec*) and Panton-Valentine leucocidin (PVL) genes.<sup>10,11,12</sup> Direct person-to-person contact is most commonly implicated in spread of staphylococcal infections, especially when the skin barrier is compromised, living conditions are crowded, and/or suboptimal hygiene; although environmental objects such as shared clothing, towels and gym equipment may also play an important role.<sup>13,14</sup> Asymptomatic colonization of nares with MRSA, as opposed to methicillin-susceptible *Staphylococcus aureus* (MSSA), is an important risk factor in healthcare settings;<sup>15,16,17</sup> however, the association is less clear in communities.<sup>18</sup>

Outbreaks of CA-MRSA have been recorded in military recruits, special warfare trainees, and active duty Army and Marine Corps personnel.<sup>1,18,19</sup> This report documents the investigation of risk factors associated with an outbreak of CA-MRSA skin and wound infections among personnel assigned to a single Navy ship during a routine deployment to the western Pacific during subsequent home-port at Pearl Harbor, Hawai'i. Although the prevalence of CA-MRSA has been increasing in Hawai'i,<sup>20,21,22</sup> an 11% prevalence of SSTI among these sailors far exceeded that which would be expected during a routine deployment (approximately 2%, D. Buxton, Fleet Surgeon, Naval Forces Mid-Pacific, personal communication). Unfortunately, no microbiology laboratory services were available to assess the etiology of wound infections for any of the cases while at sea. Each case was empirically treated with antimicrobics, with most cases requiring two or

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three courses to obtain resolution. Upon return of the ship to homeport, an investigation was conducted to assess risk factors for SSTI and CA-MRSA carriage, the prevalence of CA-MRSA among shipboard personnel, and analysis of CA-MRSA isolates from colonized personnel.

## Methods

### Study Population

The crew was assigned to an *Arleigh Burke*-class destroyer based out of Pearl Harbor, Hawai'i that had returned from a routine six-month deployment to the western Pacific region (WESTPAC) in December 2004. The crew consisted of 313 officers and enlisted sailors, both men and women. At the time of the investigation the ship was participating in routine operations. It was not dry-docked or in the shipyards undergoing maintenance work.

### Surveillance Studies

Participation was voluntary, and each crewmember was informed of the purpose of the investigation and desired information outcomes. Those willing to participate signed an informed consent form prior to enrollment.

This investigation consisted of two parts. The first was a questionnaire of basic demographic and on-board personal hygiene habits. The second part consisted of surveillance cultures collected from both nares and the left axilla of each crew member to assess colonization rates. Specimen collection was performed during a two day "underway period", when the ship was conducting local operations in the vicinity of O'ahu. Swab specimens were cultured specifically for *S. aureus*, and susceptibility testing was performed on isolates.

### Laboratory Characterization of CA-MRSA Strains

Swabs from axilla and nares were plated to 5% sheep blood agar plates (REMEL Inc, Lenexa, KS or Hardy Diagnostics, Santa Maria, CA) and incubated for 48 hours in 5-7% CO<sub>2</sub>. Identification (Vitek system, bioMerieux Inc., Hazelwood, MO) and broth dilution susceptibility testing to ampicillin/sulbactam, cefazolin, clindamycin, erythromycin, oxacillin, penicillin, trimethoprim-sulfamethoxazole, and vancomycin was

conducted on the according to standard methods<sup>23</sup>. Oxacillin resistance was confirmed using MRSA Screen Agar (REMEL Inc). If broth dilution indicated erythromycin resistance and clindamycin susceptibility, isolates were evaluated for inducible macrolide-lincosamide-streptogramin B resistance (iMLS) by "D-zone" test.<sup>24</sup>

### PFGE of CA-MRSA isolates

Seventeen CA-MRSA isolates were analyzed. Preparation and data analysis were as described by McDougal, *et. al.*,<sup>25</sup> with minor modifications. PFGE typing of MSSA was not conducted. PFGE gels were photographed (Gel Doc 1000, BioRad, Hercules, CA) and saved as a TIFF file for analysis (BioNumerics v3.5, Applied Maths, Austin, TX). Reference standard *S. aureus* NCTC #8325 in lanes one, five, ten, and fifteen were used to normalize each gel, and percent similarities were calculated using the Dice coefficient with an optimization of 0.50% and band tolerances of 1.5%. The resulting matrix was used to generate a dendrogram using the unweighted paired group method using arithmetic mean (UPGMA).

### Population Statistical Analyses

Descriptive population characteristics were analyzed to assess the significance of the associations between CA-MRSA carriage, demographic, and hygiene variables. Chi-square and Fisher's exact tests were used to determine significance between proportions at p<0.05, and logistic regression was conducted, with variables considered for inclusion if initial significance was p<0.05 from univariate analysis. STATA software (version 8.0, 2003) was used for analyses.

## Results

All 296 of crew members present at the time of the screening consented to participate, which was 94.6% of the total population (296/313). Of the crew who participated, swabs from 266/296 (89.9%) were included in the study; the others were discarded administratively because those crew members had been assigned to the ship less than 2 weeks prior to screening, which was subsequent to the deployment outbreak. Overall, 266/313 (85.0%) crew members

**Table 1.** Antimicrobial susceptibility patterns of *Staphylococcus aureus* isolates.

Antimicrobial	Susceptibility, n (%)					
	Ampicillin/ Sulbactam	Cefazolin	Clindamycin	Erythromycin	Penicillin	Trimethoprim/ Sulfamethoxazole
MSSA	55 (100%)	55(100%)	50 (91%)	32 (58%)	18 (33%)	55 (100%)
CA-MRSA	0 (0%)	0 (0%)	18 (100%)	14 (78%)	0 (0%)	18 (100%)

73 isolates had complete susceptibility testing

MSSA: Methicillin-susceptible *Staphylococcus aureus*

CA-MRSA: Community-associated methicillin-resistant *Staphylococcus aureus*

were included. *Staphylococcus aureus* was isolated from seventy-three crew members (27.1%), which is consistent with national prevalence data for that time period.<sup>9</sup> Eighteen of those isolates were MRSA (18/73, 24.7%) with an overall prevalence of 6.8% (18/266), which is about 4 times the expected colonization rate.<sup>9</sup>

Table 1 shows the *S. aureus* and MRSA susceptibility patterns for the antimicrobics tested. Among all isolates (MSSA and MRSA), 100% were susceptible to trimethoprim/sulfamethoxazole (Table 2). All MRSA were susceptible to clindamycin, although 5 MSSA isolates possessed iMLS based on “D-zone” test. All of the MRSA isolates tested except one were USA300 Pulsed-Field Types (PFT). The predominant pattern was USA300.0114 along with some common variants, which is a widely disseminated strain of community-associated MRSA (CA-MRSA) in the U.S.<sup>13,25</sup> and Hawai‘i.<sup>22</sup>

Table 2 lists statistical analysis of key demographics. There was a significantly higher risk of CA-MRSA carriage (but not MSSA carriage) associated with a history of taking antimicrobics within the past 12 months (OR=2.88, p=0.036), at least one visit to the medical department within the past 12 months (OR=3.32, p=0.011), and self-reported history of skin problems within the previous 12 months (OR=2.73, p=0.032).

Higher *S. aureus* carriage (MRSA or MSSA) was not associated with infrequent changing of bed linens (< 1 time / mo), showering (≤ every other day), or uniform laundering (≤ every other day). Neither age, smoking, surgery in the previous 12 months, nor number of months aboard the ship were significant predictors for either type of *S. aureus* colonization.

There was no significant association between hot-racking (workers from different shift using the same bed) or berthing space and either type of *S. aureus* carriage. There was no statistically significant increase in either type of *S. aureus* carriage associated with any self-reported primary workspace, although crew members who reported working “all over the ship” (n=12, 4.51%) had increased MRSA carriage (OR=4.65, p=0.031).

## Discussion

This report identified a high prevalence of CA-MRSA (24.7% of isolates) carriage among sailors (6.8% overall) following an outbreak of SSTI while on 6-month sea duty aboard a ship home-ported at Pearl Harbor. Even though carriage rates nationally had increased from 0.8% in 2001-2002 to 1.5% in 2003-2004 (9), the 6.8% prevalence is four times the expected value. Specific factors were associated with increased CA-MRSA carriage in this group, the most important of which appeared to be outpatient health care and a recent history of skin problems. Colonization

**Table 2.** Statistical Analysis of Potential Colonization Factors

Workspace	OR:MRSA	p	OR:MSSA	p
Topside duty	0.15	0.699	<b>5.18</b>	<b>0.023</b>
Duty throughout the ship	<b>5.52</b>	<b>0.019</b>	0.19	0.663
Engineering	0.01	0.913	3.08	0.79
Galley	2.89	0.089	1.28	0.257
Sonar	1.22	0.270	0.06	0.808

### Personal Factors

Antibiotics within 12 months	<b>4.75</b>	<b>0.029</b>	0.47	0.492
Sick call visit within 12 months	<b>7.07</b>	<b>0.008</b>	0.01	0.909
Skin problem* within 12 months	<b>4.88</b>	<b>0.027</b>	0.67	0.415
Hospitalized within 12 months	1.88	0.171	<b>4.08</b>	<b>0.043</b>
Surgery within 12 months	1.02	0.312	1.20	0.273
Shower < once every other day	0.85	0.358	0.31	0.574
Change bed linens < once per month	0.06	0.813	0.45	0.500
Change uniform < once every other day	0.76	0.382	0.15	0.699

### Logistic Regression Analysis

Topside duty	N/A	N/A	<b>0.13</b>	<b>0.051</b>
Duty throughout the ship	<b>4.65</b>	<b>0.031</b>	N/A	N/A
Antibiotics within 12 months	<b>2.88</b>	<b>0.036</b>	N/A	N/A
Sick call visit within 12 months	<b>3.32</b>	<b>0.011</b>	N/A	N/A
Skin problem* within 12 months	<b>2.73</b>	<b>0.032</b>	N/A	N/A
Hospitalized within 12 months	N/A	N/A	<b>3.30</b>	<b>0.055</b>

MSSA: Methicillin-susceptible *Staphylococcus aureus*  
 CA-MRSA: Community-associated methicillin-resistant *Staphylococcus aureus*

\*Self-reported skin problems (n; %) included abscess (9; 3.4%), acne (18; 6.8%), boil (7; 2.3%), infection (31; 11.7%), razor bumps (17; 6.4%), rash (25; 9.4%), other (18; 6.8%)

with MRSA can significantly increase outcome risk factor for infection in various healthcare settings;<sup>14,15,16</sup> however, its role in predisposing individuals to community-associated infections is not clear.<sup>3,18</sup> Other investigators have documented problems with current definitions,<sup>26</sup> and perhaps this indicates that present classifications are too simplistic to categorize the behavior of this microorganism in populations. It may be appropriate to expand the accepted definition of HA-MRSA beyond such recent risk factors as hospitalization, surgery, long-term care residency, dialysis, and invasive medical devices,<sup>13</sup> or acknowledge absence of these criteria do not exclude significant interaction with healthcare systems.

Surprisingly, suboptimal personal hygiene practices such as not showering on a regular basis or infrequent uniform laundering were not statistically associated with colonization. Crew members in cramped workspaces such as Sonar and Engineering were not statistically more likely to have nasal colonization with *S. aureus* than crew members of other workspaces even though working in warm moist environments could potentially predispose people to colonization and/or higher bacterial densities on skin or mucosal surfaces. Furthermore, contamination of crowded workplace environments with multi-user fomites such as keyboards, tools, and other equipment may also lead to higher colonization of individuals, but the only statistically significant workplace trend for MRSA carriage were duties that required presence throughout the ship. Consequently while general sanitation measures are still advisable, controlling staphylococci based on berthing, military occupation, or workspace need more study before targeted control strategies would be supported by data. Crew members should be monitored by medical or public health personnel knowledgeable in the operation and maintenance of naval vessels in an effort to identify trends and institute/enforce personal hygiene or environmental sanitation countermeasures to decrease the impact of *S. aureus* colonization or infection.

Genetic analysis by PFGE confirmed that the predominate CA-MRSA strain colonizing the crew was USA300 PFT. The USA300 PFT is typical of those associated with community-acquired skin and soft tissue infections in the U.S.<sup>4,13,14,25</sup> and Hawai'i,<sup>22</sup> and has been associated with outbreaks in prisons,<sup>27,28</sup> team athletics,<sup>29,30,31</sup> and military training.<sup>1</sup> This is the first documentation of high colonization rates of CA-MRSA on a military surface ship subsequent to outbreak levels of SSTI at sea. Decolonization regimens with topical agents and/or antibacterial washes is controversial in both healthcare<sup>32,33,34</sup> and community environments<sup>35,36</sup> especially considering frequent recolonization<sup>33</sup> and growing concern over development of antimicrobial resistance.<sup>34</sup>

Genetic analysis was consistent with retrospective PFGE strain characterization of CA-MRSA in Hawai'i during 2001-2003.<sup>22</sup> The colonization strain was typical of mainland USA300 CA-MRSA phenotypes in that most (70%) isolates were resistant to erythromycin and did not have inducible clindamycin resistance,<sup>24,25</sup> although 5 MSSA isolates were shown to have inducible macrolide-lincosamide-streptogramin B resistance (iMLS).

Establishment and transmission of CA-MRSA, or even MSSA, into closed environments such as military transport vessels constitutes a potential risk to both crewmember health and the operational readiness of their units. Severe clinical manifestations of CA-MRSA SSTI can rapidly affect the effectiveness of a military workforce, and adequate treatment that often requires surgical drainage in combination with aggressive antimicrobial therapy which can be problematic, especially in remote locations. Infection control audit of *S. aureus* isolates by submission location at the tertiary treatment facility for military forces in the Pacific demonstrated a dramatic 12.8-fold surge in outpatient isolates from 2002 (n=22) through 2003 (n=106) to 2004 (n=282), while inpatient isolates increased a challenging, but much smaller 31% during the same 3-year period (n=52, 65, and 68, respectively). Further breakdown of risk factors was not available; however, the increase may be partially explained by increased awareness of CA-MRSA leading to more aggressive cultivation practices, as well as demand for management of recurrent or recalcitrant infections. Even more alarming is data indicating that a clone of CA-MRSA first described in the southwest Pacific is actually a re-emerging descendant of the notorious phage-type 80/81 which caused pandemic hospital disease in the 1950s and 1960s.<sup>37</sup>

Careful surveillance of cellulites and wound infections may lead to the first indication that general sanitation measures must be emphasized and enforced. The baseline rate of CA-MRSA carriage among personnel may predispose crews to infection, but more study is needed to supply data to support this hypothesis and the credibility of targeted interventions. Personal hygiene improvement programs and epidemiologic trending, along with laboratory analysis of implicated microbial isolates, are critical components in disease control and should be standard measures in order to counter infectious disease threats.

## Disclaimer

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