Factors associated with *Staphylococcus aureus* nasal carriage among healthy people in Northern China

X. Yan1,5, Y. Song3, X. Yu3, X. Tao1,5, J. Yan3, F. Luo5, H. Zhang1,5, J. Zhang3, Q. Li3, L. He1,5, S. Li2, F. Meng1,5, J. Zhang1,5 and H. Grundmann4

1) State Key Laboratory for Infectious Disease Prevention and Control, National Institute for Communicable Disease Control and Prevention, Chinese Center for Disease Control and Prevention, Beijing, China, 2) Chaoyang Center for Disease Control and Prevention, Beijing, China, 3) Heilongjiang provincial Centre for Disease Control and Prevention, Harbin, China, 4) Department of Medical Microbiology, University Medical Center Groningen, Rijksuniversiteit Groningen, The Netherlands and 5) Collaborative Innovation Center for Diagnosis and Treatment of Infectious Diseases, Hangzhou, China

### Abstract

There is still limited knowledge about the prevalence and risk factors of nasal carriage for *Staphylococcus aureus* among healthy carriers in China. We investigated 2448 healthy adults (≥18 years of age) from Beijing (n = 1530) and Harbin (n = 918) by nasal screening. Participants were checked for carriage of *S. aureus*, and health-related and demographic information between 2009 and 2011 was gathered. A total of 403 *S. aureus* (403/2448, 16.5%) were recovered, 8 of which were methicillin resistant (8/2448, 0.33%). Three factors were independently associated with *S. aureus* nasal carriage: Harbin as city of residence (odds ratio (OR) = 2.0, 95% confidence interval (CI) = 1.41 to 2.85), age ≥24 years (OR = 1.77, 95% CI = 1.30–2.44) and non-Han ethnicity (OR = 1.58, 95% CI = 1.05 to 2.38). On the basis of population genetic analysis using multiple locus variable number of tandem repeats analysis (MLVA) and spa typing, MLVA complex (MC) 398 and MC5a were the most prevalent clonal lineages in this collection. In multivariate models, residing in Harbin (OR = 1.77, 95% CI = 1.07–2.92) and having household members in the healthcare profession (OR = 3.69, 95% CI = 1.14–11.92) were factors associated with carriage of clonal lineage MC398. On the other hand, female sex (OR = 3.15, 95% CI = 1.35–7.33) and a history of chronic liver disease (OR = 16.93, 95% CI = 2.91–98.59) were associated with the clonal lineage MC5a. The three most common spa types were t571 (10.9%), t189 (9.9%) and t701 (7.2%). These findings provide insight into the determinants of nasal carriage and ecology for some of the most successful strains of *S. aureus* among healthy people in Northern China.

Clinical Microbiology and Infection © 2014 European Society of Clinical Microbiology and Infectious Diseases. Published by Elsevier Ltd.

**Keywords:** Epidemiology, healthy carriers, nasal carriage, spa typing, *Staphylococcus aureus*

**Original Submission:** 24 April 2014; **Revised Submission:** 20 July 2014; **Accepted:** 19 August 2014

Editor: G. Lina

**Article published online:** 29 October 2014

---

**Introduction**

*Staphylococcus aureus* is a leading cause of hospital-associated and community-onset bacterial infections in humans. The most important factors which contribute to the success of *S. aureus* as a pathogen are believed to be the ability to persist as a commensal, resistance to multiple antimicrobial agents and the diverse repertoire of virulence determinants [1,2].

*Staphylococcus aureus* can colonize multiple sites of the human body, but the anterior nares appear to be the main...
ecological niche [3]. In healthy whites, it is estimated that 20% are persistent carriers and an additional 30% intermittent carriers, while approximately 50% are noncarriers. There are three lines of evidence that support the view that S. aureus nasal carriage is associated with a higher chance to develop staphylococcal infections. First, the rates of infection are higher in persistent carriers than others [4]. Second, high-resolution molecular typing using pulsed-field gel electrophoresis has shown that infecting strains of S. aureus were indistinguishable from carriage isolates previously isolated from the external nares of patients who later developed an invasive infection [5,6]. Finally, eradication of this microorganism is regarded as an effective means for reducing infections in surgical and dialysis patients [4,7].

Over the past decade, reports about community-onset methicillin-resistant S. aureus (MRSA) infections have raised concern about the public health implications of S. aureus transmission among healthy individuals. Therefore, unravelling the risk factors for carriage of S. aureus is crucial for understanding the transmission potential of both MRSA and methicillin-sensitive S. aureus (MSSA). To date, there have been only few reports on the prevalence and the risk factors of S. aureus nasal carriage in China. Previous studies revealed 15.4% to 23.1% S. aureus nasal carriage in Chinese medical students from different regions, of which 3.0% to 9.4% were MRSA [8,9]. Another study revealed a similar nasal carriage rate (20%) in 1044 military volunteers from Beijing with no MRSA strains identified [10]. Both studies focused on populations that typically lived under crowded conditions and thus had higher opportunities for transmission. It still remains unclear whether carriage rates and risk factors among the Chinese general population are in the same range. We therefore performed a population-based survey to determine the prevalence and risk factors of S. aureus nasal carriage in two cities in Northern China.

Materials and methods

Population and study design

A cross-sectional study was conducted in two northern cities, Beijing and Harbin. Individuals presenting for mandatory occupational health screenings from food and public service industries as well as public health workers were chosen as healthy volunteers for the present survey. Between 2009 and 2011, 1530 and 918 nasal swabs were sampled in Beijing and Harbin, respectively. A self-administered questionnaire was completed by each volunteer to collect pertinent demographic and medical information, as well as factors that are potentially related to S. aureus nasal carriage and transmission as identified in the literature.

Bacterial strains

Nasal swabs from both nares were enriched in tryptic soy broth (Oxoid, Basingstoke, England, UK) with 7% NaCl at 37°C for 24 hours, plated onto mannnitol salt agar (Oxoid) and cultured at 37°C for 24 hours. Presumptive S. aureus colonies were confirmed by colony morphology, Gram staining, catalase production, coagulate production using the SlideX Staph Plus kit (Murex Biotech, Kent, France) and polymerase chain reaction (PCR) for the nuc and mecA genes [11].

Molecular typing and Panton-Valentine leukocidin (pvl) gene detection

Multiple locus variable number of tandem repeats analysis (MLVA) was carried out for all 403 isolates, and representative strains of each MLVA complex (MC) were analysed by multi-locus sequence typing (MLST) in a previous unpublished study. All the isolates were also characterized using spa typing [12]. The pvl gene was detected by PCR, as previously described [13].

Simpson’s index of diversity and 95% confidence intervals were used to calculate the genetic diversity of strains by Ridom EpiCompare software, version 1.0 (Ridom GmbH, Münster, Germany).

Potential risk factors

Several variables were investigated as potential risk factors of S. aureus nasal carriage. These included general demographic variables such as age, sex, ethnicity and immune system impairment. Immune system impairment was defined as diagnosis of primary and secondary immunodeficiency disorders, and systemic immune suppressive therapy was also included. Additional risk factors, such as skin and soft tissue infections, hospitalization, use of antibiotics and frequent contact with animals or animal products in the past 6 months, were also recorded. At the same time, we were also interested in transmission between family members at the household level. Therefore, risk factors of other household members were also investigated (Online Appendix S1).

Statistical analysis

The questionnaires were manually imported into EpiData (v3.02) software (EpiData Association, Odense, Denmark). Statistical comparisons were performed with SPSS (PASW Statistics 18.0.3) software (IBM, Armonk, NY). The only continuous variable, age, was transformed into a categorical variable using the quartiles of the frequency distribution (≤24, >24–30, >30–40, >40 years). Furthermore, the different occupations were grouped into four categories that involved the following: (1) physical contact with healthy people (such as hairdressing and kindergarten teacher); (2) physical contact with animals or animal products (such as animal handlers, meat...
processing personnel, cooks); (3) physical contact with patients and patient material (such as healthcare personnel); and (4) nonphysical contact with people or animals (remaining occupations). Categorical variables were compared by the chi-square test or by the Fisher exact test. Odds ratios (OR), 95% confidence intervals (CI), and p values were calculated. A p value of \( \leq 0.05 \) was considered statistically significant. Logistic regression models were applied to determine independent risk factors. Multiple logistic regression analysis was carried out by entering all the independent variables associated with the outcome, with an α error accepted to the level of p < 0.2.

**Ethical considerations**

The study was approved by the ethical committee of the National Institute for Communicable Disease Control and Prevention, Chinese Center for Disease Control and Prevention. Written consent was obtained from all participants.

**Results**

**Characteristics of study subjects**

From 2009 to 2011, a total of 2448 volunteers from two cities were enrolled onto this study, 1530 of whom were from Beijing and 918 from Harbin. The majority of the volunteers were women (1617/2446, 66.1%). Ages ranged from 18 to 74 years (mean 32.4, standard deviation 10.3). Of the 2448 volunteers, 403 (16.5%) carried *S. aureus*, including 8 MRSA carriers (0.33%). *Staphylococcus aureus* carriage in Harbin (197/918, 21.46%) was more frequent than in Beijing (206/1530, 13.46%) (p < 0.001).

**Epidemiological factors associated with *S. aureus* carriage**

Variables associated with *S. aureus* carriage in the univariate analysis are shown in Table 1. Statistically significant factors included: age \( \leq 24 \) years, ethnicity, non-Han, residing in Harbin, immune system impairment and hospitalization of a household member within the past year. Three independent risk factors remained associated in the multiple logistic regression analysis (Table 1). These consisted of Harbin as city of residence (OR = 2.0, 95% CI = 1.41 to 2.85), age \( \leq 24 \) years (OR = 1.77, 95% CI = 1.30–2.44) and non-Han ethnicity (OR = 1.58, 95% CI = 1.05 to 2.38).

**Factors associated with strains belonging to successful clonal lineages**

In the present collection MC398 and MCSa were the most prevalent complexes, representing 21.0% and 11.7% of all isolates, respectively. The present study sought to assess the factors associated with nasal carriage for strains belonging to these two lineages. Multivariate logistic regression showed that residing in Harbin (OR = 1.77, 95% CI = 1.07–2.92) and having household members in the healthcare profession (OR = 3.69, 95% CI = 1.93 to 6.99) remained associated with nasal carriage. Additionally, hospitalization of a household member (OR = 1.77, 95% CI = 1.17–2.69) and having household members in the healthcare profession with MRSA carriers (OR = 1.57, 95% CI = 1.01–2.42) were associated with nasal carriage in Harbin.

### Table 1. Univariate and multivariate analysis of risk factors associated with *Staphylococcus aureus* nasal carriage in 2446 healthy people in Northern China during 2009–2011

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Carriers (n = 400), n (%)</th>
<th>Noncarriers (n = 2046), n (%)</th>
<th>Univariate</th>
<th>Multivariate logistic</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>OR</td>
<td>95% CI</td>
<td>p</td>
<td>OR</td>
</tr>
<tr>
<td>Sex, female</td>
<td>249 (15.4%)</td>
<td>1368 (84.6%)</td>
<td>0.82</td>
<td>0.65–1.02</td>
</tr>
<tr>
<td>Age</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>( \leq 24 ) years (n = 661)</td>
<td>135 (20.4%)</td>
<td>526 (79.6%)</td>
<td>1.52</td>
<td>1.13–2.06</td>
</tr>
<tr>
<td>( &gt;24 ) to 30 years (n = 642)</td>
<td>101 (15.7%)</td>
<td>541 (84.3%)</td>
<td>1.11</td>
<td>0.81–1.52</td>
</tr>
<tr>
<td>( &gt;30 ) to 40 years (n = 584)</td>
<td>84 (14.4%)</td>
<td>500 (85.6%)</td>
<td>1.00</td>
<td>0.72–1.39</td>
</tr>
<tr>
<td>Race, non-Han (n = 147)</td>
<td>34 (23.1%)</td>
<td>113 (76.9%)</td>
<td>1.59</td>
<td>1.07–2.37</td>
</tr>
<tr>
<td>City of residence</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Beijing (n = 1229)</td>
<td>171 (13.9%)</td>
<td>1058 (86.1%)</td>
<td>1.03</td>
<td>0.74–1.44</td>
</tr>
<tr>
<td>Harbin (n = 820)</td>
<td>175 (21.3%)</td>
<td>645 (78.7%)</td>
<td>1.74</td>
<td>1.24–2.42</td>
</tr>
<tr>
<td>Occupation</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Contact with animal products (n = 775)</td>
<td>139 (17.9%)</td>
<td>636 (82.1%)</td>
<td>1.75</td>
<td>0.73–4.17</td>
</tr>
<tr>
<td>Contact with patients (n = 66)</td>
<td>10 (15.2%)</td>
<td>56 (84.8%)</td>
<td>1.43</td>
<td>0.48–4.22</td>
</tr>
<tr>
<td>Nonphysical contact with healthy people (n = 1531)</td>
<td>240 (15.7%)</td>
<td>1291 (84.3%)</td>
<td>1.49</td>
<td>0.63–3.51</td>
</tr>
<tr>
<td>Education</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Primary school (n = 125)</td>
<td>16 (12.8%)</td>
<td>109 (87.2%)</td>
<td>0.34</td>
<td>0.08–1.46</td>
</tr>
<tr>
<td>Middle school (n = 1107)</td>
<td>184 (16.6%)</td>
<td>923 (83.4%)</td>
<td>0.47</td>
<td>0.12–1.82</td>
</tr>
<tr>
<td>High school (n = 791)</td>
<td>132 (16.7%)</td>
<td>659 (83.3%)</td>
<td>0.47</td>
<td>0.12–1.83</td>
</tr>
<tr>
<td>University or higher (n = 407)</td>
<td>64 (15.7%)</td>
<td>343 (84.3%)</td>
<td>0.44</td>
<td>0.11–1.73</td>
</tr>
<tr>
<td>Immunity system disease, yes (n = 6)</td>
<td>3 (50%)</td>
<td>3 (50%)</td>
<td>5.16</td>
<td>1.04–25.65</td>
</tr>
<tr>
<td>Hospitalization in past half year, yes (n = 31)</td>
<td>7 (22.6%)</td>
<td>24 (77.4%)</td>
<td>1.51</td>
<td>0.65–3.53</td>
</tr>
<tr>
<td>Antibiotic use in past half year, yes (n = 180)</td>
<td>66 (17.4%)</td>
<td>114 (82.6%)</td>
<td>1.09</td>
<td>0.82–1.46</td>
</tr>
<tr>
<td>Frequent skin puncture in past half a year, yes (n = 126)</td>
<td>20 (15.9%)</td>
<td>106 (84.1%)</td>
<td>0.97</td>
<td>0.59–1.58</td>
</tr>
<tr>
<td>Regular contact sports activities, yes (n = 229)</td>
<td>39 (17.0%)</td>
<td>190 (83.0%)</td>
<td>1.06</td>
<td>0.74–1.53</td>
</tr>
<tr>
<td>Smoking</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ex-smoker (n = 289)</td>
<td>41 (14.2%)</td>
<td>248 (85.8%)</td>
<td>0.83</td>
<td>0.58–1.18</td>
</tr>
<tr>
<td>Smoker (n = 413)</td>
<td>67 (16.2%)</td>
<td>346 (83.8%)</td>
<td>0.97</td>
<td>0.73–1.30</td>
</tr>
<tr>
<td>Regular contact with living animals, yes (n = 215)</td>
<td>32 (14.9%)</td>
<td>183 (85.1%)</td>
<td>0.89</td>
<td>0.60–1.31</td>
</tr>
<tr>
<td>Household member hospitalization within 1 year, yes (n = 97)</td>
<td>23 (23.7%)</td>
<td>74 (76.3%)</td>
<td>1.63</td>
<td>1.01–2.64</td>
</tr>
</tbody>
</table>

OR, odds ratio; CI, confidence interval.
95% CI = 1.14–11.92) were factors associated with increased risk of carrying MC398 strains (Table 2). On the other hand, being of female sex (OR = 3.15, 95% CI = 1.35–7.33) and having a history of chronic liver disease (OR = 16.93, 95% CI = 2.91–98.59) heightened risk associated with MC5a carriage (Table 3).

### Spa typing and Panton-Valentine leukocidin (pvl) gene detection

In total, the 403 isolates were assigned to 77 spa types, including 10 novel spa types, where 56 spa types were identified in Beijing and 42 in Harbin. Nineteen spa types were found in both cities, corresponding to 69.98% of all isolates. The top 11 spa types in both cities are shown in Table 4. The most commonly encountered spa types in this study were t571/CC398/ST398/MC398 (10.9%), t189/CC1/ST2139/MC437 (9.9%) and t701/ST6/ST2114/MC1933 (7.2%). Furthermore, our analyses revealed that carriage isolates had the same genetic diversity in both sampling locations, with a diversity index of 0.952 (0.941–0.964).

Moreover, the 8 MRSA strains belonged to different spa types. Two isolates had spa type t034/CC398/ST398/MC398, and one isolate each of spa type t2431/Singleton/ST2799/MC482, t437/CC59/ST59/MC621 and t116/CC45/MLST45/MC45. The remaining two MRSA isolates were not typeable by spa typing.

Interestingly, the pvl gene was only detected among nine MSSA isolates (9/403, 2.2%), of which two had spa type t002/CC5/ST5/MC5a and one each had spa type t011/CC398/ST398/MC398, t091/CC7/ST7/MC7, t1376/CC88/ST2148/MC5b, t071/CC6/ST2114/MC1933, t167/CC5/ST25/MC674, t645/CC121/ST123/MC123 and t7611/CC22/ST22/MC22.

### Discussion

We found nasal carriage with *S. aureus* in 16.5% of our study population. This finding coincides with the prevalence observed among recruits in a military camp (16%) [10] and medical college students in another study (15.4%) [9]. Cross-sectional studies conducted outside of China found prevalence estimates ranging from 8% to 37% among different populations, where 0% to 8.6% was MRSA [14–17]. The low prevalence of MRSA (0.36%) and the heterogeneity of spa types suggest that there were no singularly expanding MRSA clones among the study population.

Higher *S. aureus* carriage rates were published for whites [18,19], men [20], individuals with obesity [14], children [9] and...
people with underlying diseases [4], especially skin disorders. We identified a significantly higher carriage among adults who are ethnically non-Han Chinese. Previous studies have shown that the human leukocyte antigen (HLA) DR3 antigen predisposes healthy individuals and transplant recipients to S. aureus nasal carriage with S. aureus [21,22]. Thus, population-specific frequencies of HLA haplotypes may explain differential susceptibilities between ethnic groups. However, HLA DR3 haplotype frequencies among the non-Han S. aureus carriers have not been investigated.

Interestingly, our study showed that the presence of household members who are healthcare personnel appeared to be a risk factor for MC398 carriage. Importantly, approximately one third of all isolates showed the same spa types with community-associated MSSA and hospital-associated MSSA infections [24]. This finding lends further support to the notion that S. aureus carriers are at risk of autoinfection.

In conclusion, our study showed that younger people (≤24 years) and ethnically non-Han individuals were more likely to be colonized by S. aureus. Furthermore, the presence of household members who are healthcare personnel appeared to be a risk factor for MC398 carriage. Importantly, approximately one third of all isolates showed the same spa types with community-associated MSSA and hospital-associated MSSA in some hospitals. These findings could be helpful for understanding the determinants of S. aureus nasal carriage and transmission routes of some successful strains in Northern China.

### Transparency declaration

The authors declare that they have no conflicts of interest.

### Acknowledgements

This work was supported by the National Natural Science Foundation of China (grant 81301463), by the State Key Laboratory for Infectious Disease Prevention and Control Fund of China (2012KLLD020), and by an educational grant from the Graduate School of Medical Sciences of the University of Groningen, the Netherlands.

### Appendix A. Supplementary data

Supplementary data related to this article can be found at http://dx.doi.org/10.1016/j.cmi.2014.08.023.

### References