Since January 2020 Elsevier has created a COVID-19 resource centre with free information in English and Mandarin on the novel coronavirus COVID-19. The COVID-19 resource centre is hosted on Elsevier Connect, the company's public news and information website.

Elsevier hereby grants permission to make all its COVID-19-related research that is available on the COVID-19 resource centre - including this research content - immediately available in PubMed Central and other publicly funded repositories, such as the WHO COVID database with rights for unrestricted research re-use and analyses in any form or by any means with acknowledgement of the original source. These permissions are granted for free by Elsevier for as long as the COVID-19 resource centre remains active.
Brief report

Tracking sources of *Staphylococcus aureus* hand contamination in food handlers by spa typing

Jeffery Ho BSc (hons), Maureen V. Boost PhD, MPH, Margaret M. O’Donoghue PhD *

Squina International Centre for Infection Control, School of Nursing, The Hong Kong Polytechnic University, Hung Hom, Kowloon, Hong Kong

Key Words:
Persistent carriage
Nasal colonization
Hand hygiene
Environmental contamination

Hand contamination of food handlers with *Staphylococcus aureus* is an important risk factor for staphylococcal food poisoning (SFP). Hands may act as vectors transferring the organism to food where enterotoxins may be formed and result in acute gastroenteritis on ingestion. Nasal carriers and contaminated foods are possible sources of *S aureus* contamination.1 However, studies of *S aureus* carriage in food handlers have mainly focused on nasal colonization,2 with limited investigation of the origins of hand contamination. Although hand and environmental contamination in Spanish food handlers was recently investigated, there was no attempt to match sources of contaminating organisms and nasal carriage.3 A Japanese study that investigated transmission using ribotyping demonstrated spread from contamination of cooking equipment and another worker by a colonized food handler.4 Because SFP is an important cause of foodborne illness, identification of sources of contamination is essential to determine appropriate hygiene interventions. This study aimed to investigate the sources of *S aureus* contaminating hands of food handlers.

**MATERIALS AND METHODS**

A total of 548 food handlers from 14 catering establishments located throughout Hong Kong were nasally swabbed by a trained researcher using a moistened transport swab on 2 occasions, 3-6 months apart, to define nasal carriage status. Swabs were transferred to the laboratory for culture within 2 hours of collection. Persistent carriers were defined as individuals with both specimens positive with the same spa type, whereas those positive on 1 occasion were classified as transient carriers. On the second visit, direct fingertip imprint specimens were collected. For any establishment where hand contamination rates exceeded the average by 10%, sampling was repeated 1 month after reinforcement of handwashing training.

Ethical approval was obtained from the University Ethics Committee. Each subject was provided with an information sheet and gave written consent.

Nasal swabs were incubated overnight in 5% salt-supplemented brain-heart infusion broth (Oxoid, Basingstoke, UK) at 37°C before subculture onto SA Select agar (Bio–Rad UK Ltd, Hemel, Hempstead, UK). Imprints of fingerprints of the dominant hand were obtained by latex agglutination (Remel, Lennexa, Kan) and characterized by spa typing and comparison with the Ridom database.5 To determine the degree of similarity of strains, Simpson’s diversity index (D) was calculated using standard formulae.

**RESULTS**

On the second sampling 132 individuals (24%) were nasally colonized and *S aureus* was present on the hands of 16.6% (91 out of 548). Hand contamination was absent at 3 establishments but at 1 site (C) there was a much higher contamination rate (44 out of 62; 71%). Following reinforcement of handwashing, restesting yielded a rate similar to that of the other 10 sites (11.1%) (Table 1).

---

1. Handwashing should be supplemented by effective environmental disinfection.
2. Attempts to match sources of contaminating organisms and nasal carriage.
3. Studies of *S aureus* carriage in food handlers have mainly focused on nasal colonization.
4. A Japanese study that investigated transmission using ribotyping demonstrated spread from contamination of cooking equipment and another worker by a colonized food handler.
5. Simpson’s diversity index (D) was calculated using standard formulae.

---

*Address correspondence to Margaret M. O’Donoghue, PhD, School of Nursing, The Hong Kong Polytechnic University, Hung Hom, Kowloon, Hong Kong. E-mail address: margaret.o.donoghue@polyu.edu.hk (M.M. O’Donoghue). Part of this study was presented at the 15th Asia Pacific Congress of Clinical Microbiology and Infection, Kuala Lumpur, Malaysia, November 2014. This study was funded by a research grant from the School of Nursing, The Hong Kong Polytechnic University, Kowloon, Hong Kong. Conflicts of interest: None to report.*

Copyright © 2015 by the Association for Professionals in Infection Control and Epidemiology, Inc. Published by Elsevier Inc. All rights reserved.

| Material and Methods | Time of Collection | Technique Used | Source of Contamination |
|----------------------|--------------------|----------------|------------------------|
| *Staphylococcus aureus* | 3-6 months | Nasal swabbing | Hand contamination |
| Simpson’s diversity index (D) | Calculated using standard formulae | | |
Of 53 subjects with hand contamination, the strain present on 4 sets of hands was identical with their own nasal strain. Three of these 4 workers were persistent carriers. Hand carriage isolates of 29 out of 49 noncolonized food handlers revealed identical spa types to the nasal isolates from persistently colonized coworkers. Of the remaining 20 hand-colonized subjects, 10 had isolates matching spa types of transient carriers within the same workplace, whereas the remainder yielded spa types distinct from the nasal isolates of their coworkers (Table 1). The risk of a noncolonized worker being contaminated by a strain carried by a persistently colonized coworker was considerably higher (odds ratio, 5.66; 95% confidence interval, 2.12–15.45; \( P = .002 \)). Before improvement of handwashing in the poorly compliant establishment, 46.3% of exogenous contamination was from persistent carrier strains, 12.2% was from transient carriers’ strains, and the remaining 41.5% was from unrelated strains. The 3 persistent carriers each harboring the same strain on their hands and noses appeared to be superspreaders (Fig 1). The proportions from persistent, transient, and other sources became 83% (5 out of 6), 16.7% (1 out of 6), and 0, respectively, after improvements in handwashing (Table 1).

Spread of a persistent carrier’s spa type to a coworker’s hands was observed in 3 sites. At both sites D and J, there was a single nasal carrier of t189 with contaminated hands and other noncolonized workers had hand contamination with this strain. A similar scenario was observed with t437 at site F (Table 1).

In total, 13 spa types present on hands matched those of persistent carriers and 10 matched those of transient carriers. Three spa types from persistent carriers predominated: t189 (45.8%), t127 (14.6%), and t338 (12.5%). Diversity index determination revealed that strains of persistent carrier origin (\( D = 0.862 \)) are more closely related than those of other origins (\( D = 1.00 \)).

**DISCUSSION**

By use of a large population of food handlers, repeated sampling to determine carriage status, and use of spa typing, we were able to reveal that persistent nasal carriers are likely to be the most important source of hand contamination, accounting for more than half of the isolates. Such transmission would most likely occur indirectly, as a result of nasally contaminated hands of colonized workers contaminating the environment, utensils, or food, which are then in contact with other food handlers. The lower diversity of spa types from hand isolates matching nasal isolates from persistent carriers rather than those of transient carriers indicated that the majority of contamination may be originating from a few persistent carriers. The most frequently isolated strain—t189—is commonly isolated from human infections in Southeast Asia and has been isolated from pork products, including local roasted pork. Types t091, t127, and t701 have been implicated in food poisoning outbreaks in China, and types t127 and t084 have been implicated from SFP isolates from Germany.

Persistent carriers harbor higher loads of the organism and may contaminate their hands and surrounding environments. Environmental contamination can lead to transmission to hands of noncolonized workers who may become transient carriers and/or transfer the organisms via their hands to food. Up to 90% of nasal carriers have been shown to simultaneously harbor the bacteria in their noses and on their hands. However, in our study, endogenous hand contamination was surprisingly rare, which might be attributable to regular handwashing, because reinforcement reduced isolation of these strains at site C. Environmental contamination from persistent carriers may also involve aerosols from these workers in addition to the usually considered nose-to-hand-to-environment transmission route. Reinforcement of handwashing also led to elimination of spa types from sources other than colonized coworkers. This indicates handwashing before commencement of work removes contamination from outside the workplace. Since the severe acute respiratory syndrome outbreak, hand hygiene has improved as a result of government initiatives, including appointment of hygiene supervisors to monitor handwashing. The overall low level of hand contamination we found was similar to the 9% reported for Finnish airline-catering workers and 8.4% reported for Spanish food handlers.

**Table 1**

| Site | No. workers (sample 2) | P | T | N | Hand positive (n [%]) | Persistent carriers | Transient carriers | Others (endogenous spread) |
|------|------------------------|---|---|---|-----------------------|---------------------|----------------------|---------------------------|
| A    | 26                     | 4 | 4 | 18 | 6 (23.1)              | t024 (2)           | t127, t2532         | t592 (T)                 |
| B    | 18                     | 4 | 0 | 14 | 1 (5.5)               | t085               |                      |                           |
| C    | 54                     | 10| 6 | 38 | 6 (11.1)              | t021, t127, t164, t189, t338 t437 |
| D    | 28                     | 6 | 3 | 19 | 5 (17.8)              | t189 (2)           | t032, t2546         | t189 (P)                 |
| E    | 125                    | 22| 11| 92 | 9 (7.2)               | t084 (2), t189 (3), t616 t091, t5864 t213 |
| F    | 66                     | 11| 3 | 52 | 9 (13.6)              | t282, t338, t437 (2), t7738 t701, t3092 t668 t1437 (P) |
| G    | 43                     | 4 | 2 | 37 | 5 (11.6)              | t084 (2), t189 t616 t2919 |
| H    | 24                     | 3 | 3 | 18 | 1 (4.2)               | t189               |                      |                           |
| I    | 58                     | 6 | 3 | 49 | 3 (5.2)               | t050, t189 t084   |
| J    | 45                     | 6 | 7 | 32 | 5 (11.1)              | t189               | t571, t035, t183 t189 (P) |
| K    | 23                     | 5 | 2 | 16 | 3 (13.0)              | t437               | t082, t701          |
| L, M, N | 30                  | 7 | 0 | 23 | 0                      |                     |                      |                           |
| Overall hand carriage (n = 53) |                      |   |   |   | 29 (54.7%)           | 10 (18.9%)         | 10 (18.9%)           | 4 (7.5%)                  |

Diversity index

N, not a carrier; P, persistent carrier; T, transient carrier.

*Putative source of hand contamination was defined by spa typing of hand isolates. Source attributed to presence of a spa type of a hand isolate that was identical to that of a nasal isolate from a persistently or transiently colonized coworker in the same workplace.

1Spa type (number of isolates belonging to a given type, shown only if >1).

2Spa type and nasal colonization status of hand-contaminated subject.

3Site C: Second sample after handwashing training. Eight subjects had left their employment at this time, reducing the total number to 54.

4Three sites where no hand carriage was observed.
CONCLUSIONS

The majority of hand contamination appeared to be attributable to cross-contamination from persistently colonized coworkers who presumably contaminated the environment. This emphasizes the need for improvements in environmental disinfection in addition to handwashing to reduce transmission to other workers. Use of gloves and masks for those handling foods is recommended because it is not feasible to define carriage status.

References

1. Todd EC, Greig JD, Bartleson CA, Michaels BS. Outbreaks where food workers have been implicated in the spread of foodborne disease. Part 4. Infective doses and pathogen carriage. J Food Prot 2008;71:2339-73.
2. Dagnenew M, Tiruneh M, Moges F, Tekeste Z. Survey of nasal carriage of Staphylococcus aureus and intestinal parasites among food handlers working at Gondar University, Northwest Ethiopia. BMC Public Health 2012;12:1471-2458.
3. Sospedra I, Mañes J, Soriano JM. Report of toxic shock syndrome toxin 1(TSST-1)from Staphylococcus aureus isolated in food handlers and surfaces from foodservice establishments. Ecotoxicol Environ Saf 2012;80:288-90.
4. Kishimoto M, Hioki Y, Okano T, Konuma H, Takamizawa K, Kashiio H, et al. Ribotyping and a study of transmission of Staphylococcus aureus collected from food preparation facilities. J Food Prot 2004;67:1116-22.
5. Harmsen D, Claas H, Witte W, Rothganger J, Claas H, Turnwald D, et al. Typing of methicillin-resistant Staphylococcus aureus in a university hospital setting by using novel software for spa repeat determination and database management. J Clin Microbiol 2003;41:5442-8.
6. Ip M, Wang Z, Lam WY, Zhou H, Tsui S. Draft genome sequence of methicillin-resistant Staphylococcus aureus CUHK_188 (ST188), a health care-associated bacteremic isolate from Hong Kong. Genome 2014;A2. e00255-14.
7. Young CP, O'Donoghue MM, Ho J, Boost MV. High levels of Staphylococcus aureus contamination in Chinese-style roast pork. Foodborne Pathog Dis 2014;11:552-4.
8. Yan X, Wang B, Tao X, Hu Q, Cui Z, Zhang J, et al. Characterization of Staphylococcus aureus strains associated with food poisoning in Shenzhen, China. Appl Environ Microbiol 2012;78:6637–42.
9. Wattinger L, Stephan R, Layer F, Johler S. Comparison of Staphylococcus aureus isolates associated with food intoxication with isolates from human nasal carriers and human infections. Eur J Clin Microbiol Infect Dis 2012;31:455-64.
10. Wertheim H, Melles D, Vanleeuwens V, van belkum A, Verbrugh H, et al. The role of nasal carriage in infections. Lancet Infect Dis 2005;5:751–62.
11. Hatakka M, Bjorkroth KJ, Asplund K, Korkeala HJ. Genotypes and enterotoxicity of Staphylococcus aureus isolated from the hands and nasal cavities of flight-catering employees. J Food Prot 2000;63:1487-91.

Fig 1. Spread of Staphylococcus aureus between food handlers in site C before reinforcement of handwashing. Each square represents one person. The spa type on upper and lower rows indicates spa type of S aureus isolated from nose and hands, respectively.