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Original Article

Spread of *Staphylococcus aureus* between medical staff and high-frequency contact surfaces in a large metropolitan hospital

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ABSTRACT

Objective: To examine whether bacteria are transferred between the hands of medical staff and high-frequency contact surfaces within and between departments of a major metropolitan hospital, and to further analyze the patterns of cross-transmission.

Methods: Microbiological samples were collected from the hands of 112 hospital employees as well as from 120 high-frequency contact surfaces in four hospital departments. Samples were collected on agar plates, analyzed for the presence of *Staphylococcus aureus* or methicillin-resistant *S. aureus* (MRSA) by standard microbiology testing, and partially genotyped using pulsed-field gel electrophoresis.

Results: Genetically identical MRSA was identified on the surface of an electrocardiography device in the medical intensive care unit and on the same type of device in the neurosurgical unit. Genetically similar *S. aureus* was identified on an infusion pump in the medical intensive care unit and on the hands of several doctors in a different department who regularly use that pump. Genetically identical *S. aureus* was also identified on bedside rail restraint in the medical intensive care unit and on the hands of the nurse in the neurosurgical unit. Finally, genetically similar MRSA was identified both on the surface of an electrocardiography device and on the suction apparatus in the medical intensive care unit.

Conclusion: Cross-contamination of *S. aureus* or MRSA on medical workers' hands and contact surfaces was demonstrated within and between departments of a large metropolitan hospital. Improvements are needed in medical staff hygiene habits and in the cleaning of high-frequency contact surfaces to help prevent and control nosocomial infections.

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1. Introduction

Hospital-acquired infections are a serious global health issue and pose risks to medical staff, patients, and the broader community [1,2]. In fact, hospital-acquired infections are the fourth most frequent cause of death in the United States behind heart disease, cancer, and stroke [3]. In China, 25–33% of patients admitted to the hospital acquire nosocomial infections [4]. These infections place a substantial economic burden in countries worldwide [5–8].

Contamination of medical workers' hands and contact surfaces in the hospital are key sources of hospital-acquired infections [9–11]. Contact surfaces near patient areas have been classified as low-, medium-, or high-frequency contact surfaces [12]. High-frequency contact surfaces include nurses' work computers, multi-parameter electrocardiography (ECG) monitors, glucose meters, suction catheters, infusion pumps, worktables, bedside rail restraints, and door handles. Few studies have compared these different surfaces to determine their respective contributions to hospital-acquired infections. Given that high-frequency contact surfaces are more likely to be contaminated, we focused on them in the present work. Many pathogenic bacteria have been shown to live on these surfaces, including coagulase-negative *Staphylococcus, Enterococcus, Staphylococcus aureus,* and methicillin-resistant *S. aureus* (MRSA). As nosocomial infection caused by MRSA is very difficult to treat, MRSA has attracted much more public attention than any other bacteria [13]. Much of the literature on hospital-acquired nosocomial infections has focused on identifying which microorganisms and which surfaces are involved, while few studies have examined how microorganisms travel from one surface to another or between surfaces and medical workers. Some studies have documented cross-contamination of *S. aureus, Enterococcus sp.,* and *Acinetobacter sp.* between medical workers' hands and their mobile phones [14,15].

To our knowledge, no studies directly examine bacterial transmission between hospital contact surfaces and medical staff. We therefore sought to examine how bacteria is transmitted between the hands of medical personnel and high-frequency contact surfaces in multiple departments of a major metropolitan hospital in China.

2. Materials and methods

2.1. Ethical considerations

This study was approved by the Ethics Committee of China–Japan Friendship Hospital prior to data collection. Informed consent was obtained from all medical workers who participated.

2.2. Subjects and locations of samplings

Microbiological sampling was performed in a 1500-bed tertiary care hospital providing service to a large area in Beijing, China on February 20–21, 2014. Samples were collected on Replicate Organism Detection And Counting (RODAC) plates (Becton, Dickinson and Company, Japan).

A total of 112 samples were collected from medical workers via cluster sampling, including 112 samples from the self-reported dominant hand of 30 medical workers from the medical intensive care unit, 30 from the surgical intensive care unit, 22 from the urology department, and 30 from the neurosurgical department (Table 1). Medical workers included doctors, nurses, nursing assistants, and cleaners. Nursing assistants and cleaners were classified as "other personnel." Workers were excluded if they had recently washed their hands or if their hands showed obvious signs contamination with patient body fluids such as blood.

Table 1 – Numbers of hospital workers and high-frequency contact surfaces sampled for *S. aureus* and MRSA in a large metropolitan hospital, by worker type and department.

Sample	Department				Total
	Surgical intensive care unit	Medical intensive care unit	Urology	Neurosurgery	
Hand					
Doctor	13	16	8	8	45
Nurse	14	14	10	17	55
Others	3	0	4	5	12
Total	**30**	**30**	**22**	**30**	**112**
Contact surface					
Worktable	3	2	3	3	11
Bedside rail restraint	7	3	6	6	22
Door handle	5	4	4	5	18
Work computer	4	4	4	4	16
Multi-parameter ECG monitor	7	3	7	6	23
Glucose meter	2	2	2	2	8
Joint of sputum suction tube and suction apparatus	4	3	0	0	7
Infusion pump	4	3	1	1	9
Fixed-line telephone	0	0	2	2	4
Beeper	0	0	1	1	2
Total	**36**	**24**	**30**	**30**	**120**

Table 2 – Frequency of *S. aureus* detection on medical workers' hands and high-frequency contact surfaces in different departments

Department	No. of *S. aureus* strains		No. of MRSA strains		Separation rate of *S. aureaus* (%)	
	Medical staff's hands	High-frequency contact surfaces	Medical staff's hands	High-frequency contact surfaces	Medical staff's hands	High-frequency contact surfaces
Surgical intensive care unit	2	1	0	0	6.7	2.8
Medical intensive care unit	2	4	0	2	6.7	16.7
Urology unit	2	0	0	0	9.1	0
Neurosurgery unit	1	2	0	1	3.3	6.7
Total	**7**	**7**	**0**	**3**	**6.3**	**5.8**

In the same four departments, a stratified random sampling method was carried out to take 120 high-frequency contact surface samples (Table 1). Sampling locations were stratified based on the department and on the type of high-frequency contact surface (e.g. worktable or bedside rail restraints). Numbers were assigned to all high-frequency contact surfaces, numbers were written on equally-sized pieces of paper, mixed thoroughly, and placed into eight envelopes corresponding to the eight surfaces. On the day of sampling, someone not involved in the study drew 30 random numbers. These high-frequency contact surfaces were sampled in all four departments, yielding a total of 120 samples. Locations were excluded if they had recently been cleaned. Excluded objects were replaced with alternative objects.

2.3. *Sampling method*

Microbiological samples were collected on RODAC plates [7], first described by Hall and Hartnett [16] in 1964, and allows for rapid and easy sampling. The plate is gently pressed onto the object being sampled, and the plate is then placed directly in the incubator. Samples from hands were collected by pressing from thumb to pinky, and then the heart of palm onto the plate.

RODAC plates, which contained fluorogenic culture medium (catalog no. desoxycholate, BD; lot 3211387) were cultured at 35 °C for 48 h. Colony numbers were counted with the naked eye. Bacterial strains were identified by analyzing the samples on a BD Phoenix Automated Microbiology System, and using the chemical properties described by the American Society for Microbiology's Manual of Clinical Microbiology.

2.4. *Partial genotyping of* S. aureus *and MRSA isolates*

To determine whether strains of *S. aureus* and MRSA isolated from hands and contact surfaces were the same or different, we analyzed the bacterial strains using pulsed-field gel electrophoresis, as previously described [17].

3. Results

3.1. *Frequency of detection of* S. aureus *and MRSA*

Among the 112 samples collected from medical workers' hands, *S. aureus* was detected in seven workers (6.3%). The frequency of detection was higher among workers in the surgical and medical intensive care units than in the neurosurgery departments. None of the seven *S. aureus*-positive samples were found to contain MRSA. All sampling results are summarized in Table 2.

We detected *S. aureus* on seven surfaces of the 120 high-frequency contact surfaces sampled (Table 2). As observed in samples from workers' hands, the frequency of detection on surfaces was muchhigher in the medical intensive care units than in the other departments. Of the seven *S. aureus*-positive surfaces, three were found to be positive for MRSA—the joint of the sputum suction tube and suction apparatus and an ECG monitor in the medical intensive care unit, and an ECG monitor in the neurosurgery department.

3.2. *Strain typing of* S. aureus *and MRSA isolates*

The *S. aureus* and MRSA isolated from surfaces and hands were analyzed by pulsed-field gel electrophoresis to determine whether they were the same strains (Fig. 1). MRSA from the multi-parameter ECG monitor in the medical intensive care unit and the MRSA from the ECG monitor in the neurosurgery department showed the same banding pattern, suggesting that they are the same strain (pattern J in Table 3). S.

Table 3 – Analysis of PFGE results.

Lane	Sample description		PFGE pattern
	Department	Source	
1	SICU	Doctor's hand	A
2	SICU	Doctor's hand	B
3	MICU	Doctor's hand	C
4	MICU	Doctor's hand	D
5	UU	Caregiver's hand	E
6	UU	Doctor's hand	F
7	NU	Nurse's hand	G
8	SICU	Suction catheter	H
9	MICU	Infusion pump	B′
10	NU	ECG monitor	I
11	MICU	Bedside rail restraint	G
12*	MICU*	ECG monitor	J
13*	NU*	ECG monitor	J
14*	MICU*	Suction catheter	J′

Note: *: MRSA detected; SICU: surgical intensive care unit; MICU: medical intensive care unit; UU: urological unit; NU: neurosurgical unit; PFGE: pulsed-field gel electrophoresis.

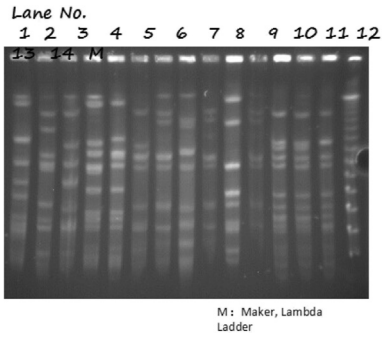

Fig. 1 – Pulsed-field gel electrophoresis analysis of *S. aureus* and MRSA isolated from hospital workers' hands and high-frequency contact surfaces.

aureus from one nurse in the neurosurgery department and *S. aureus* from a bedside rail restraint in the medical intensive care unit also showed the same banding pattern (pattern G in Table 3). Lastly, *S. aureus* from the hand of a doctor in the surgical intensive care unit and *S. aureus* from an infusion pump in the medical intensive care unit showed a similar banding pattern (pattern B and B′ in Table 3). We were informed of a doctor who regularly used the infusion pump. The doctor disclosed to us that he may have touched the infusion pump when while in the medical intensive care unit for consultations, thereby adding to evidence of *S. aureus* transfer between medical workers and contact surfaces and between hospital departments. MRSA from a multi-parameter electrocardiography device and MRSA from the joint of sputum suction tube and suction apparatus in the medical intensive care unit also showed similar banding patterns (pattern J and J′ in Table 3). MRSA therefore appears to have also transferred between different high-frequency contact surfaces within the same department.

4. Discussion

Hospital-acquired infections can spread through a cross-contamination chain linking infected patients, hospital workers' hands, instruments, and contact surfaces [18]. Although numerous studies have sought to identify the microorganisms responsible for nosocomial infections, few studies have systematically examined how the microorganisms spread from infected patients to others in the hospital. Recent advances in partial genotyping using pulsed-field gel electrophoresis allow tracking the spread of bacteria throughout the hospital [19,20]. Here we use this approach to demonstrate the transmission of *S. aureus* and MRSA between medical workers' hands and high-frequency contact surfaces both within and between departments in a large metropolitan hospital.

Our results are consistent with those of study at the Innsbruck Medical University Hospital in the Austria [14], where the authors found cross-contamination between hands and mobile phones of medical staff in the department of anaesthesia and critical care medicine. The study also reports apparent cross-contamination between medical staff's hands and other objects in the hospital, though the study focused on transmission between mobile phones and hands. We extend that work by focusing on hand-surface transmission.

Our sampling of hospital workers and surfaces was limited to two days, meaning our results represent a snapshot of *S. aureus* and MRSA distribution in the hospital. Future work should do more extensive screening over an extended period of time, which could provide a more detailed insight into how infectious bacteria can spread within a hospital. Further work should also examine a wider range of bacteria, as well as viruses. Here we chose to focus on *S. aureus* since it is one of the most frequent causes of nosocomial infections. Other common bacterial infections warranting further investigations include *Escherichia coli, Pseudomonas aeruginosa, Klebsiella pneumonia, Enterococcus faecium* [21], and *Acinetobacter baumannii* [22], as well as viruses reported to cause nosocomial infections including human adenovirus (Had V) [23] and hepatitis B and C viruses [24].

5. Conclusion

Our results confirm the ease with which pathogens such as MRSA can travel within and between hospital departments, and highlight the need for concerted efforts to prevent and control nosocomial infections. Several measures have been described in research studies [25], as well as in recommendations from authority organizations such as the American Healthcare Infection Control Practices Advisory Committee [26]. Measures include disinfecting the surfaces of high-frequency contact objects surrounding patients when they are discharged or transferred to another department, periodically checking high-frequency contact surfaces in the intensive care unit for the presence of *S. aureus* and MRSA, improving hygiene awareness of medical staff and encouraging them to wash their hands at the five optimal times of the day [27], improving the cleaning level of high-frequency contact surfaces, and isolating patients with *S. aureus* or MRSA infections as quickly as possible. In addition, hospitals should ensure the rational use of broad-spectrum antimicrobial agents to reduce the risk of generating drug-resistant strains.

Statement for conflict of interest

We wish to confirm that there are no known conflicts of interest associated with this publication and there has been no significant financial support for this work that could have influenced its outcome.

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REFERENCES

[1] Shen ZY. An overview of the global nosocomial infection control. Preventive medicine discipline development blue book. 2006.
[2] Yu GY. Study on the control of nosocomial infection within inpatient wards at Dong zhi men Hospital of Beijing University of Chinese Medicine. Beijing University of Chinese Medicine; 2011.
[3] Yu ZX. A study on influencing factors and Direct economic losses of nosocomial infection in a tertiary teaching Hospital's integrated ICU. Shandong University; 2011.
[4] He YQ. Prevalence monitoring to nosocomial infections in 2010. Chin J Nosocom 2011;21:4451–2.
[5] Weinstein RA. Nosocomial infection update. J Infect Control 2000;1:14.
[6] Jarvis WR. Selected aspescts of the socioeconomic impact of nosocomial infections: mortality, cost and prevention [J]. Infect Control Hosp Epidemiol 1996;17(8):552–7.
[7] Ivanov DV, Krapivina IV, Galeeva EV. Nosocomial infections: epidemiology, pathogenesis, etiology, antibacterial therapy, and prophylaxis. Antibiot Khimioter 2005;50(12):19–28.
[8] Ball MJ, Douglas JV. IT, patient safety, and quality care. J Healthc Inf Manag 2002;16(1):28–33.
[9] He HY, Lin WQ, Huang XQ, Lv FL, Sheng Li. Control hands pollution to prevent nosocomial infection. Chin J Nosocom 2008;18(10):1407–9.
[10] Shen CL. A survey of status quo of hands washing of medical and nursing staffs. J Nurs Res 2004;18(10A):1718–9.
[11] Hu BL, Zong ZY. Prevention and control of operation site infection. Shanghai Science and Technology Press; 2012.
[12] Huslage K, Rutala WA, Sickbert-Bennett E, Weber DJ. A quantitative approach to defining "high-touch" surfaces in hospitals. Infect Control Hosp Epidemiol 2010;31(8):850–3.
[13] Gould IM. Costs of hospital-acquired methicillin resistant *Staphylococcus aureus* (MRSA),and its control. Int J Antimicrob Agents 2006;28:379–84.
[14] Jeske HC, Tiefenthaler W, Hohlrieder M, Hinterberger G, Benzer A. Bacterial contamination of anaesthetists' hands by personal mobile phone and fixed phone use in the operating theatre. Anaesthesia 2007;62(9):904–6.
[15] Khivsara A, Sushma TV, Dahashree B. Typing of *Staphylococcus aureus* from mobile phones and clinical samples. CurrSci 2006;90(7):910–2.
[16] Hall LB, Hartnett MJ. Measurement of the bacterial contamination on surfaces in hospitals. Public Health Rep 1979:1021–4.
[17] Tenover FC, Arbeit RD, Goering RV, Mickelsen PA, Murray BE, Persing DH, et al. Interpreting chromosomal DNA restriction patterns produced by pulsed-field gel electrophoresis: criteria for bacterial strain typing. J Clin Microbiol 1995;33(9):2233–9.
[18] Zheng PM, Shu JH, Qiu YX. The administration effects of hand hygiene compliance of medical staff. Chin J Nosocom 2010;17:2652.
[19] Hunter SB, Vauterin P, Lambert-Fair MA, Van Duyne MS, Kubota K, Graves L, et al. Establishment of a universal size standard strain for use with the PulseNet standardized pulsed-field gel electrophoresis protocols: converting the national databases to the new size standard. J Clin Microbiol 2005;43(3):1045–50.
[20] Hou TY, Huang DL, Chen ZL, Zhang YP, Bai XJ. Molecular epidemiology of clinical isolates of imipenem-resistant acinetobacter baumannii from intensive care unit. Chin J Nosocom 2010;20(16):2371–4.
[21] Wnag L, Yang C, Zhang Q, Han B, Zhuang JJ, Chen M, et al. Prevalence and features of pathogenic bacteria in the department of hematology without bone marrow transplantation in Peking Union Medical College Hospital from 2010 to 2012. Zhongguo Yi Xue Ke Xue Yuan Xue Bao 2014;36(4):439–45 [Article in Chinese].
[22] Ma MY, Xu J, Yu N, Huang GM. Analysis of drug resistance of *Acinetobacter baumannii* and its related factors in ICU. Zhonghua Wei Zhong Bing Ji Jiu Yi Xue 2013;25(11):686–9 [Article in Chinese].
[23] Aoki K, Kaneko H, Kitaichi N, Watanabe H, Ishida S, Ohno S. Bioinformatics on new human adenoviruses causing nosocomial infection. Nihon Ganka Gakkai Zasshi 2013;117(9):721–6 [Article in Japanese].
[24] Rinonce HT, Yano Y, Utsumi T, Heriyanto DS, Anggorowati N, Widasari DI, et al. Hepatitis B and C virus infection among hemodialysis patients in Yogyakarta, Indonesia: prevalence and molecular evidence for nosocomial transmission. J Med Virol 2013;85(8):1348–61.
[25] Allegranzi B, Pittet D. Role of hand hygiene in healthcare-associated infection prevention. J Hosp Infect 2009;73(4):305–15.
[26] Boyce JM, Pittet D. Guideline for hand hygiene in heath-care settings. Recommendations of the healthcare infection control practices advisory committee and the HIPAC/SHEA/APIC/IDSA hand hygiene task force. Am J Infect Control 2002;30(8):S1–46.
[27] Sax H, Allegranzi B, Chraïti MN, Boyce J, Larson E, Pittet D. The World Health Organization hand hygiene observation method[J]. Am J Infect Control 2009;37(10):827–34.