Colonization pressure adjusted by degree of environmental contamination: A better indicator for predicting methicillin-resistant *Staphylococcus aureus* acquisition

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Background: Colonization pressure has been confirmed as an important risk factor for methicillin-resistant *Staphylococcus aureus* (MRSA) acquisition among inpatients, but their precise relationship has not been well investigated. Because MRSA carriers can disperse MRSA into their immediate environment with different abilities, the relationship among colonization pressure, the degree of MRSA contamination in environment surrounding MRSA carriers, and MRSA transmission should be explored to facilitate efficient implementation of infection control measures.

Methods: Active MRSA screening and environmental sampling were performed in a 23-bed emergency ward (EW) and a 7-bed respiratory intensive care unit (RICU) between March 2009 and February 2010. Weekly colonization pressure (WCP) was modified to WCPe (WCP adjusted by degree of environmental contamination). Receiver operating characteristic curve and correlation analyses were used to analyze the accuracy of WCPe in predicting MRSA acquisition and their correlation, respectively.

Results: We found that 34.1% (858/2,520) of the immediate environmental sites of MRSA-positive patients were contaminated with MRSA. The areas under the receiver operating characteristic curve of WCPe reached as high as 0.784 (95% confidence interval, 0.659-0.909; $P < .01$) for the EW and 0.866 (95% confidence interval, 0.766-0.967; $P < .01$) for the RICU. Spearman's correlation coefficient (r) indicated a positive and significant correlation between WCPe and MRSA acquisition rate in the subsequent weeks for both the EW ($r = 0.45$; $P = .001$) and RICU ($r = 0.51$; $P < .001$).

Conclusion: Active MRSA screening combined with targeted environmental contamination monitoring could be a more efficient measure for determining the magnitude of the MRSA reservoir in wards occupied by MRSA carriers. WCPe showed moderate prediction accuracy for both the EW and the RICU, and a threshold WCPe value may be used as a predictor to enhance infection control measures, especially for medical facilities without a sufficient number of single rooms.

Key Words: Nosocomial transmission; environmental monitoring; infection control.

Methicillin-resistant *Staphylococcus aureus* (MRSA) infection is a leading cause of morbidity and mortality among inpatients. Patients colonized with MRSA are at increased risk for developing infections.[1,2] Thus, preventing MRSA acquisition remains an important component of infection control. Risk factors for MRSA acquisition include pretreatment with antibiotics, involvement of invasive procedures or indwelling devices, prolonged hospitalization, exposure to a patient with nosocomially acquired MRSA, increasing care dependency, and colonization pressure (CP).[3-7]

Among the foregoing factors, CP was thought to be the only independent risk factor for MRSA acquisition,[3] which reflects the reservoir of MRSA in specific wards, mainly in intensive care units (ICUs). The precise effects of CP on MRSA acquisition and their relationship are still not well described, however.

Based on analysis of the dynamic transmission cycle involving MRSA carriers, their immediate environment, and the hands of HCWs and susceptible individuals, immediate environmental contamination caused by

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MRSA carriers can be considered a connector between MRSA carriers (the origin of CP) and susceptible patients through the hands of health care workers (HCWs) (the major transmission route). In previous studies, CP generated from each MRSA carrier was deemed to be the same, but the degree of contamination in the immediate environment of MRSA carriers (MRSA dispersal) varied widely.[8-10] The importance of environmental contamination caused by MRSA carriers in MRSA transmission has been elaborated in several previous studies.[11-14] Accordingly, the degree of MRSA contamination in environments surrounding MRSA carriers somewhat reflects the role of the individual carriers in MRSA transmission.

In this study, we combined weekly CP (WCP) and the degree of contamination in the immediate environment of MRSA carriers into a single term, WCP adjusted by degree of environmental contamination (WCPe). We compared the accuracy of WCP and WCPe in predicting MRSA transmission.

METHODS

Screening of MRSA carriage

The study was conducted within Tongren Hospital, a 1,600-bed general tertiary care and university-affiliated teaching hospital in Beijing, China. Between March 2009 and February 2010, screening for MRSA carriage at the time of admission was performed in the emergency ward (EW) and a 7-bed respiratory ICU (RICU). Because many critically ill patients admitted to the EW were usually transferred to other units, and given the high incidence rate of MRSA infection in the RICU, identification and prevention of MRSA carriage is especially important in these 2 wards. The EW was divided into 2 sections, a 7-bed ICU and a 16-bed open-bay ward. Based on the required level of nursing care, patients admitted to the EW are frequently moved between these 2 sections before being transferred to another unit or being discharged. We screened patients on admission to the EW who met any of the following criteria: transfer from other wards within the hospital, transfer from another hospital, receiving home health care, use of antibiotic within the previous year, or a history of an antibiotic-resistant organism.[6,7,15] All patients admitted to the RICU were screened. Specimens were obtained from the nose, throat, axilla, groin, and any wound (when appropriate) using swabs. Patients with MRSA isolated either in the screening or clinical cultures were defined as MRSA-imported cases. Thereafter, patients in the open-bay wards had nasal swab samples obtained every 3 days when in the unit with an MRSA carrier, and all others were screened weekly. All patients admitted to the RICU were screened every 2 days until discharge or transfer to another unit. Routine clinical cultures also were obtained as clinically indicated. A patient with MRSA isolated either from screening or clinical samples more than 48 hours after admission was identified as a hospital-acquired case. MRSA carriers were accommodated in single rooms or isolated locally (bedside isolation), with barriers (large curtains) placed between beds when single rooms were not available. The usual turnaround time for MRSA screening results before placing a patient in isolation was less than 48 hours. Before the start of sampling, each patient provided written consent. The study was approved by Tongren Hospital's Ethics Committee.

Infection prevention and control practices

Besides isolation precautions, both HCWs and visitors were required to wear protective gowns and masks when performing health care activities or visiting MRSA-positive patients. HCWs were required to wear gloves when performing health care activities, and visitors were required to wash their hands using alcohol-based solution before and after visiting these patients. The HCWs routinely use alcohol-based solution for hand disinfection. Daily air disinfection was performed using the MKJ1200 disinfecting equipment (an air disinfection device based on high-voltage electrostatic disinfection effect, Shanghai Jin Shi Purification Technology, Shanghai, China) running around the clock. Sodium hypochlorite solution (0.1%) was used for surface disinfection. Frequently touched environmental surfaces (eg, computer mice, keyboards, doorknobs, toilet rails, faucets, telephone handsets, call buttons) were disinfected every 3-4 hours. For the clinical (patient) areas, solid surfaces were disinfected 3 times/day for multidrug bacteria-negative patients and 4-6 times/day for multidrug bacteria-positive patients. Bed linens were changed at least once a day for each patient. For terminal environmental cleaning of MRSA isolation rooms, 0.5% sodium hypochlorite solution was used for surface disinfection, and ultraviolet light and 3% hydrogen peroxide (spraying) were used for air disinfection. Most of the disinfection work was completed by the sanitation workers in each unit. Decolonization treatment was not prescribed for patients colonized with MRSA. A rigid antibiotic restriction policy was implemented during the study, especially regarding quinolones.[6,16]

Environmental sampling

Environmental sampling was initiated when a patient was identified as MRSA-positive. The samples were collected at 8:00 a.m. (1 hour after bed linen changes and before the start of medical activities). Thirty immediate environmental sites were sampled for each MRSA-positive patient. These included 14 sites