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Higher Prevalence of Pharyngeal than Nasal *Staphylococcus aureus* Carriage in Pediatric Intensive Care Units▽

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Sensitive detection of *Staphylococcus aureus* colonization is important for epidemiologic studies, infection control, and decolonization measures. We examined the sensitivity of nasal and pharyngeal sampling for *S. aureus* colonization in 331 children admitted to intensive care units. Pharyngeal screening was more sensitive than nasal screening (92.6% versus 63.1%, $P < 0.0001$).

Health care-associated *Staphylococcus aureus* infections increase morbidity, mortality, and hospital costs. Patients with surgical site infections (SSIs) due to methicillin-susceptible *S. aureus* (MSSA) are 3.4 times as likely to die, experience median lengths of stay 9 days longer, and incur median hospital costs $23,000 greater than controls (7). Even more severe outcomes follow methicillin-resistant *S. aureus* (MRSA) infections (2, 3, 7).

S. aureus carriage is a well-known risk factor for infection. The relative risk of SSI associated with nasal colonization, compared to no colonization, is as high as 8.1, while in nonsurgical patients the relative risk of infection ranges from 1.8 to 14.0 (11). National guidelines recommend mupirocin administration for patients undergoing cardiac surgical procedures in the absence of a documented lack of *S. aureus* nasal carriage (6).

Although the nares have been considered the primary site of *S. aureus* colonization (23), recent studies in adults indicate that pharyngeal carriage may be equally or more common (4, 5, 13–17). Studies of pediatric pharyngeal carriage have assessed small numbers of subjects, but most suggest pharyngeal carriage may be common in children (1, 9, 10, 12, 19, 21). We determined the prevalence of pharyngeal carriage and compared the sensitivities of pharyngeal and nasal screening among children admitted to our hospital's intensive care units (ICUs).

(Study findings were presented in part as a slide presentation at the 2008 Interscience Conference on Antimicrobial Agents and Chemotherapy/Infectious Diseases Society of America Annual Meeting.)

The study population consisted of patients admitted to the neonatal, medical-surgical, or cardiac ICUs from February through May 2008. Patients >18 years of age or with conditions unsafe for pharyngeal swab collection, such as recent pharyngeal surgery, were excluded. The hospital's Committee on Clinical Investigation approved the study protocol.

Active surveillance cultures (ASC) for detection of MRSA carriage were already routine for ICU patients on admission and weekly thereafter. Swabs were taken from the nares and occasionally other sites (e.g., umbilicus, axilla, or groin) but not the pharynx. Nasal and pharyngeal study specimens were obtained once from each subject, at the same time as routine admission MRSA ASC, using the BBL CultureSwab system (a rayon swab packaged with Stuart's transport medium [BD Diagnostic Systems]). One swab was rotated gently in both nostrils and another upon both tonsils. Specimen collection was performed by ICU nurses, who also collect routine ASC; training was provided to assure uniform collection. Because the intent was to examine colonization on ICU admission, specimens were excluded if acquired >24 h after ICU admission. Specimens were also excluded if obtained from the pharynx or nares only in a given subject.

Study specimens were cultured in selective *Staphylococcus* broth (Difco) for 18 to 24 h at 35°C with 5% CO_2, then subcultured on Trypticase soy agar with 5% sheep's blood (BBL) and incubated as above. *S. aureus* was identified by Gram stain, catalase test, and the Staphaurex latex agglutination test for coagulase and protein A (Remel). Susceptibility testing, including testing for methicillin susceptibility, was performed using the AST-GP67 panel on the Vitek II system (bioMérieux) according to the manufacturer's instructions. Swabs for routine MRSA ASC were cultured directly on selective BBL Chromagar MRSA media (Becton, Dickinson and Company). MRSA was identified and susceptibility testing was performed as for the study specimens.

The proportions of subjects with isolation of MSSA or MRSA from the pharynx, with and without isolation from the nares, were determined. The sensitivities of pharyngeal and nasal screening were calculated using isolation from either site as the gold standard and compared using Fisher's exact test. Differences between subjects and patients not enrolled in the study were assessed using the chi-square and Fisher exact tests. Analyses were performed using Stata 9.0.

Of 551 patients admitted to the ICUs, 331 were enrolled, 137 were ineligible, and 83 were eligible but missed. Patients not enrolled tended to be older, with a greater proportion over

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TABLE 1. Patterns of *Staphylococcus aureus* carriage

Result[a] for pharynx	Result for nares	No. of subjects	% of all subjects (95% CI)	% of *S. aureus* carriers (95% CI)
Positive	Positive	68	20.5 (16.2–24.9)	55.7 (46.8–64.7)
Negative	Negative	209	63.1 (57.9–68.3)	—[b]
Positive	Negative	45	13.6 (9.9–17.3)	36.9 (28.2–45.5)
Negative	Positive	9	2.7 (0.96–4.5)	7.4 (2.7–12.1)

[a] Positive, *S. aureus* isolated; negative, no *S. aureus* isolated.
[b] —, not applicable.

TABLE 2. Patterns of MRSA carriage[a]

Study pharyngeal culture result	Study nasal culture result	Routine MRSA ASC result	No. of MRSA carriers
MRSA	MRSA	MRSA	6
MRSA	MSSA	No MRSA	1
MRSA	No *S. aureus*	No MRSA	2
MRSA	MSSA	MRSA	1
MSSA	MRSA	MRSA	1
MSSA	No *S. aureus*	MRSA	1

[a] Among MRSA carriers, the nares were the source of all routine MRSA ASC. With isolation of MRSA from either the pharyngeal culture or routine nasal ASC as the gold standard, the sensitivity of pharyngeal cultures for detection of MRSA was 83.3%, while the sensitivity of routine nasal ASC was 75.0%, a difference that was not statistically significant.

1 year of age ($P = 0.001$), but had a similar MRSA carriage rate (4.0% versus 2.8% in study subjects) as measured from routine ASC.

The subjects' median age was 6 months (range, 1 day to 18 years). The most common reasons for ICU admission were postsurgical care (40.2%) and respiratory support (17.8%). One-third of subjects (33.5%) were transferred to the ICU from another health care setting (another unit at the same hospital, another hospital, or a long-term care facility), while the rest were admitted from home or at birth. Most (88.2%) had a chronic condition. One-third of subjects (35.0%) were intubated. Most (75.9%) had received antibiotics during the week before admission.

One hundred twenty-two subjects (36.8%) were carriers of MSSA and/or MRSA in the nares and/or pharynx (Table 1); 113 (34.1%) were pharyngeal carriers, and 45 (13.6%) were colonized in the pharynx alone. By our culture-based methods, the sensitivity of pharyngeal screening for detection of any *S. aureus* strain (MSSA or MRSA) was found to be 92.6% (95% confidence interval [CI], 86.4% to 96.6%), whereas the sensitivity of nasal screening was 63.1% (95% CI, 53.9% to 71.7%) ($P < 0.0001$).

Twelve subjects (3.6%) were MRSA carriers (Table 2), consistent with low colonization rates at our hospital (G. Potter-Bynoe, personal communication). Pharyngeal cultures identified 10 MRSA carriers, while routine ASC, all from the nares, identified 9. Nine carriers had isolates resistant to ≥3 antibiotic classes, suggesting health care-associated strains.

We discovered that pharyngeal *S. aureus* carriage is more common than nasal carriage among our pediatric ICU patients. The frequency of pharyngeal colonization among carriers was 92.6%, exceeding rates in adults (58 to 84%) (14, 16, 20). The frequency of nasal colonization was only 63.1%, at the low end of adult rates (62 to 74%) (14, 16, 20). Pharyngeal carriage only (36.9%) was much more common than nasal carriage only (7.4%).

Decolonization regimens sometimes fail to eliminate *S. aureus* carriage (8, 10), perhaps in part due to pharyngeal colonization. Low pharyngeal concentrations of mupirocin after nasal application might promote development of resistance (22). Additionally, the pharynx may act as a reservoir, contributing to failure of regimens focused on nares and skin colonization (10, 16, 17). Systemic antibiotics or oropharyngeal chlorhexidine may clear pharyngeal colonization, but development of resistance, feasibility of oropharyngeal application in young children, and potential adverse treatment effects are concerns (10, 18).

We focused upon children admitted to ICUs since they are at high risk for *S. aureus* colonization and subsequent infection. In addition, factors such as intubation may increase the risk of pharyngeal colonization in particular. Further studies are warranted to assess pharyngeal colonization in other pediatric populations. We evaluated carriage on admission only and did not type strains, so we could not assess risk of transmission of pharyngeal strains. Our hospital has a low MRSA prevalence. If further studies demonstrate a high prevalence of exclusively pharyngeal carriage of MRSA in pediatric patients, this finding will have implications for efforts to control transmission and infection. We used an enrichment broth rather than selective media to enhance sensitivity and thus may have missed mixed MRSA and MSSA populations if one strain outgrew another in the broth.

Our findings indicate the need to assess pharyngeal colonization as part of screening and decolonization strategies in children to avoid missing one-third of *S. aureus* carriers. Further investigation is required in settings where MRSA is endemic to understand the importance of pharyngeal carriage.

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