A Multicenter, Cross-Sectional Study on the Prevalence and Risk Factors for Nasal Colonization with *Staphylococcus aureus* in Patients Admitted to Children's Hospitals in Switzerland

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The rate of nasal carriage of *Staphylococcus aureus* and associated risk factors were determined in a cross-sectional study involving Swiss children's hospitals. *S. aureus* was isolated in 562 of 1363 cases. In a stepwise multivariate analysis, the variables age, duration of antibiotic use, and hospitalization of a household member were independently associated with carriage of *S. aureus*.

Staphylococcus aureus is an important pathogen that causes community-associated and health care–associated infections in all age groups [1, 2]. It colonizes the skin and mucosa of humans, and subsequent infections affect virtually all organ systems.

Several studies have aimed to determine the prevalence and risk factors for nasal *S. aureus* colonization in children and have had variable results [3–8]. We aimed to determine the prevalence of and risk factors for nasal *S. aureus* colonization in children requiring hospitalization.

Patients and methods. Methodological details of this multicenter, cross-sectional study involving children admitted to 9 large training hospitals in Switzerland from 16 March through 15 April 2006 have been published previously [9]. A nasal swab sample from both nostrils was collected for culture of *S. aureus* within 48 h after hospital admission, and the following comprehensive patient characteristics were obtained: date of hospital admission, date of birth, sex, reason for hospitalization, chronic underlying disease, pets in the household, history of travel abroad, hospitalizations in the previous 3 months, antibiotic use (including drug, dosage, and duration) in the preceding 3 months, previous colonization with methicillin-resistant *S. aureus* (MRSA), previous hospitalization or current employment of a family member in a medical institution, and occurrence of nosocomial *S. aureus* infection during this hospitalization.

Data were processed and analyzed by 3 of the investigators (F.D., T.E., and U.H.). Patients with a culture positive for *S. aureus* comprised the methicillin-susceptible *S. aureus* (MSSA) carriage group, and patients without a culture positive for *S. aureus* comprised the control group. Statistical analyses were performed with SAS software, version 9.1 (SAS Institute). Potential predictors of colonization with *S. aureus* were analyzed with a stepwise regression technique using logistic procedures in SAS. Independent variables were entered into the model when the associated P value was <.3 and were retained if the P value remained <.12. $P < .05$ was considered to be statistically significant.

Results. There were 1762 hospitalizations involving 1736 eligible children during the study period. A total of 356 hospitalizations (20.2%) were excluded because of parental refusal (88 hospitalizations); >48 h since hospital admission (72); and various other reasons, such as hospital discharge before the investigator could enroll the patient, language barriers, or absence of parents (196). An additional 43 patients from 1 study site were excluded because of significant protocol violations. Thus, nasal swab samples were available from 1363 hospitalizations involving 1350 patients.

S. aureus was isolated in 562 cases (41.2%); in 561 of these cases, only MSSA was isolated, and 1 patient carried both MSSA and MRSA. Prevalence of nasal colonization with *S. aureus* varied between study sites (range, 36.5%–48.0%). Of the 13 patients (1%) who were hospitalized twice, 6 had negative culture results at both hospitalizations, 4 had cultures that were positive for *S. aureus* at both hospitalizations, and 3 had negative culture results during the first hospitalization and culture results that were positive for *S. aureus* during the second hospitalization. Of 1363 hospitalizations, 906 (66.5%) involved

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Swiss citizens, 442 (32.4%) involved individuals of foreign origin who were living in Switzerland, and 15 involved individuals whose nationality was unknown.

We compared potential risk factors for colonization and demographic characteristics of 562 colonized patients with those of patients who were not colonized with *S. aureus* (table 1). Multivariate logistic regression analysis revealed that patient age ($P = .003$) and hospitalization of a household member during the previous 3 months ($P = .004$) were independent predictors for nasal colonization with *S. aureus,* whereas antibiotic use during the previous 3 months ($P < .001$) was associated with a lack of *S. aureus* colonization. Male sex, current hospitalization in a university hospital, and recent stay abroad tended to be risk factors for MSSA colonization (with *P* values ranging from .07 through .08).

Prevalence of colonization with *S. aureus* was age dependent, with prevalence peaks among children 1–2 months of age (57%) and school-age children (up to 65%; $P = .003$) (figure 1). The likelihood of being colonized with *S. aureus* increased with length of previous hospitalization of a household member: among hospitalizations of children with a household member who had been hospitalized for 2–4 days, 5–7 days, and ⩾8 days, colonization rates were 23 (41.8%) of 55 hospitalizations (95% CI, 29.0%–55.0%), 32 (51.6%) of 62 hospitalizations (95% CI, 39.6%–64.4%), and 18 (62.1%) of 29 hospitalizations (95% CI, 44.3%–79.7%), respectively ($P = .004$).

The influence of duration of antibiotic treatment and of the kind of antibiotics used was further analyzed. Among hospitalizations involving 1–3 cumulative days of antibiotic use, 37 (45.7%) of 81 (95% CI, 35.2%–56.9%) involved patients who were colonized, and this proportion decreased to 38 (38.8%) of 98 (95% CI, 29.3%–48.7%), 33 (25.6%) of 129 (95% CI, 18.4%–33.6%), and 13 (20.6%) of 63 (95% CI, 10.9%–31.1%) among hospitalizations involving 4–7 days, 8–21 days, and >21 days of antibiotic use, respectively ($P < .001$).

Among antibiotics used by patients before hospitalization, aminopenicillins (used in 45.9% of cases) and trimethoprim-sulfamethoxazole (16.4%) were most common. When we classified the different antibiotics according to their expected effectiveness against *S. aureus,* 56 (28.1%) of 199 patients (95% CI, 21.9%–34.4%) treated with an antibiotic with >60% expected effectiveness were colonized with *S. aureus,* compared with 23 (33.3%) of 69 patients (95% CI, 22.2%–44.5%) treated with an antibiotic with <30% effectiveness ($P = .415$). Both rates were lower than those for patients without any antibiotic use within the previous 3 months (colonization rate, 44.9%; $P < .001$ and $P < .06$, respectively).

Children hospitalized at the 5 university hospitals had a higher prevalence of recent antibiotic use, compared with children treated at other teaching hospitals (mean prevalence, 32.5% vs. 24.0%; $P = .002$); this is probably explained by the higher proportion of children with chronic underlying diseases hospitalized at university hospitals, compared with other teaching hospitals (percentage of hospitalized children with chronic underlying diseases, 27.3% vs. 16.0%; $P < .001$). No nosocomial *S. aureus* infections occurred.

Discussion. The finding of a prevalence of 41.2% for nasal carriage of *S. aureus* is higher than those previously reported for children (18.6%–39.2%) [4, 10, 11]. This might be explained by our highly sensitive culture method, which used a selective enrichment broth.

After stepwise multivariate analysis, the variables age, du-

Table 1. Characteristics associated with and univariate predictors of methicillin-susceptible *Staphylococcus aureus* (MSSA) carriage.

	Overall		MSSA carriage			
Variable	Proportion of hospitalizations	Percentage of hospitalizations (95% CI)	Proportion of hospitalizations	Percentage of hospitalizations (95% CI)	OR (95% CI)	*P*
Sex						
Male	732/1361	53.8 (51.4–56.7)	319/732	43.6 (40.0–47.2)	1.23 (0.98–1.54)	.067
Female	629/1361	46.2 (43.4–48.7)	243/629	38.6 (34.8–42.4)	…	
Swiss nationality	906/1348	67.2 (64.5–69.5)	370/906	40.8 (37.6–44.0)	0.93 (0.73–1.17)	.54
Chronic underlying disease	321/1346	23.8 (21.7–26.3)	124/321	38.6 (33.3–44.0)	0.87 (0.66–1.12)	.278
Presence of a pet in the household	571/1362	41.9 (39.4–44.6)	248/571	43.4 (39.4–47.5)	1.22 (0.97–1.52)	.081
Previous stay abroad	224/1363	16.4 (14.1–18.0)	80/224	35.7 (29.4–42.0)	0.77 (0.57–1.05)	.103
Duration of previous antibiotic use						
1–6 days	115/1359	8.5 (6.9–10.0)	51/115	44.3 (35.3–53.4)	1.04 (0.68–1.49)	.98
⩾7 days	255/1359	18.7 (16.7–20.8)	69/255	27.1 (21.6–32.5)	0.45 (0.33–0.62)	<.001
Previous hospitalization of family member	178/1350	13.2 (11.2–14.8)	90/178	50.6 (43.2–57.9)	1.56 (1.18–2.15)	.007
Current stay at a university hospital	951/1363	69.8 (67.6–72.4)	374/951	39.3 (36.2–42.4)	0.775 (0.61–0.98)	.035
Previous hospitalization	260/1360	19.1 (16.9–21.1)	102/260	39.2 (33.3–45.2)	0.89 (0.67–1.18)	.44
Family member working in medical institution	232/1362	17.0 (15.0–19.0)	103/232	44.4 (38.0–50.8)	1.17 (0.88–1.56)	.286
Patient age, per year	…	…	…	…	1.03 (1.01–1.05)	.010

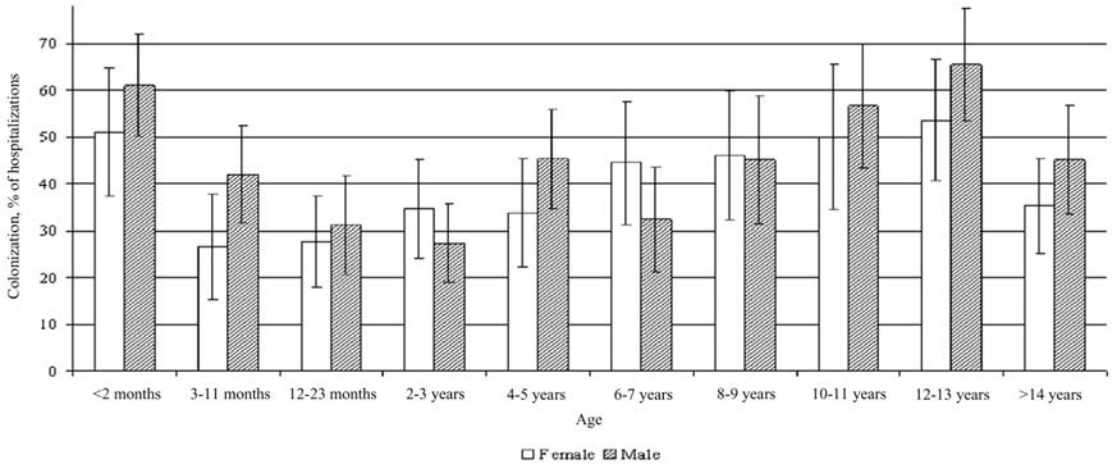

Figure 1. Methicillin-susceptible *Staphylococcus aureus* colonization rates, by age and sex. Bars, 95% CIs.

ration of antibiotic use, and hospitalization of a household member during the previous 3 months were independently related to carriage of *S. aureus.* In the National Health and Nutrition Examination Survey (NHANES) for 2001–2002, nasal MSSA and MRSA colonization prevalence estimates of 36.9% and 0.6%, respectively, were found in individuals 1–19 years of age [10]. MSSA colonization prevalence was highest (45%) among participants who were 6–11 years of age, which is in accordance with our results, although we found a further prevalence peak in young infants (who were not included in the NHANES survey).

Only a few systematic studies have addressed risk factors for MRSA and MSSA colonization among children and have had variable results [3–5, 11]. Breast-feeding, hospitalization, chronic skin conditions, and a history of indwelling catheter or other medical devices were found to be associated with *S. aureus* carriage in infants in 1 study [5]. We did not investigate these variables, because our original goal was to specifically identify risk factors for MRSA carriage. Furthermore, having a household member who works in a hospital was documented as a potential risk factor for MRSA colonization [3], and day care outside of the home and greater numbers of people in the household were risk factors for MSSA colonization in children [4]. Again, we did not obtain these variables in our survey and, therefore, cannot confirm this finding.

Age was identified in earlier studies as a significant risk factor for MSSA colonization [4, 5, 10, 11]. Based on NHANES data, an overall prevalence of *S. aureus* colonization of 32.4% was estimated, with the highest proportion (40%–50%) of colonization occurring among participants 6–11 years of age [10, 12]. In a study that determined *S. aureus* carriage among infants, a high carriage rate (40%–50%) during the first 2 months of life was found [5]. This is in agreement with our finding of an MSSA carriage peak among infants 1–2 months of age (57.0%). The reasons for a further peak among children 8–13 years of age (45.1%–65.5%) may be explained by social factors, such as household size [4] and school attendance.

In some studies, nasal *S. aureus* colonization was found to be more frequent in male patients [11, 12]. However, male sex was not identified as an independent risk factor in our study.

In contrast with previous studies, we identified recent hospitalization of household members as a possible risk factor for *S. aureus* carriage in children. Surprisingly, recent hospitalization of the patient was not an independent risk factor for MSSA carriage, in contrast with the findings of a previous study [2]. This may be explained by the effect of antibiotic treatment on MSSA carriage during a previous hospitalization period.

Recent treatment with antibiotics was associated with a lower rate of nasal *S. aureus* colonization in this and 2 previously published studies [4, 11]. Specifically, cumulative treatment decreased the likelihood of a child being colonized. The most frequently reported antibiotics were aminopenicillins and trimethoprim-sulfamethoxazole, both of which are commonly effective against >60% of MSSA isolates and, consequently, reduced the likelihood of MSSA colonization. However, because of the cross-sectional design of our study, it remains to be determined whether this is a temporary finding and, if so, how long such protection lasts.

Our study has some limitations. First, most clinical and sociodemographic data obtained were selected on the basis of the literature regarding MRSA. Therefore, other factors beyond those that were identified might also be relevant for MSSA colonization. Second, study participants had been admitted to the hospital and, therefore, are not necessarily representative of the general population of children. Furthermore, not all geographic areas of Switzerland were represented in this study. However, limited variability of *S. aureus* carriage rates between sites makes it unlikely that this introduced a significant bias.

Third, body sites other than the nose were not examined in this study. However, most other comparable studies have also focused on the anterior nares of the nose, which is the most frequent site of *S. aureus* carriage, and detection of colonization of other body sites would have important implications mainly in the case of MRSA, which did not play a significant role in our population.

In summary, the findings of this study allow an estimate of the current prevalence of *S. aureus* nasal carriage among children in our area. In addition, they provide an opportunity to identify children with an increased or decreased likelihood of MSSA carriage.

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Potential conflicts of interest. All authors: no conflicts.

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