
Risk Factors for Colonization with *Staphylococcus aureus* in Neonatal Nursery

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Colonization with hospital-acquired microorganisms increases neonatal morbidity and mortality. *Staphylococcus aureus* colonization rate differs between different populations: newborn infants, delivered mothers and medicine personal. The main aim of the current study was to investigate the transmission of some *S. aureus* strains (including methicillin-resistant *S. aureus* strain) among treated high-risk newborn infants. This was the first attempt to investigate the present epidemiological situation with respect to *S. aureus* colonization in neonatal nursery and NICU using statistical analysis. Resistant *S. aureus* strains spread through the hand of medical personnel, because newborns colonized with resistant *S. aureus* strains were not in contact with mothers. Newborns and medical personnel were colonized with antibiotic-resistant *S. aureus* strains.

Key words: newborn, colonization, *S. aureus* strains, methicillin resistance

INTRODUCTION

Hospitals worldwide are faced with increasingly rapid emergence and spread of antibiotic-resistant bacteria. Some available data show the development of antibiotic resistance in specialized departments such as intensive care units, burns, transplant wards, and dialysis units.

Within the first 1 to 2 weeks of life, the neonate that have remained in the special care nursery are likely to be colonized with perinatally (endogenously) and nosocomially acquired flora. Bacteria start to colonize the skin, respiratory tract, and intestines as soon as the newborn has left the sterile womb. Immaturity of the immune system of newborn favours transmission and multiplication of resistant microorganisms (1). Therefore hospital-acquired infections are diagnosed not only in the intensive care units, but also in term newborn departments, where the newborns seem likely to have no any problems.

Colonization sites of *S. aureus* can vary, but most often they are found in two main carriage sites – the nose and, to a lesser extent, the perineum. Examples of populations with an increased frequency of *S. aureus* carriage are newborns, hospital workers, hemodialysis patients and those with skin disor-

ders such as eczema. The main source of *S. aureus* colonizing the infants is the skin flora of the people in the infants' environment. Airborne and environmental contamination are uncommon, except where patients with tracheostomies are unable to handle their secretions. Medical personnel is the main transmission chain among hospitalized patients (2).

S. aureus has been isolated at an increasing rate from infants' stools during the last decades, but it is not known whether this species can colonize and persist in the intestinal microflora. Staphylococcal colonization rates in newborns' stool increased continuously from 16% to 73% by 6 months (3). However, most children and 40% of adults are nasal carriers of *S. aureus*. *S. aureus* is a cause of skin pustules, pemphigus neonatorum, conjunctivitis, umbilical infection and breast abscess. Different exotoxines, among them the enterotoxines, could play a role in the shaping of the infant's lymphoid system.

The frequency of infections influenced by methicillin-resistant *S. aureus* (MRSA) strains has increased dramatically within hospitals throughout the world (4). The presence of MRSA in hospitalized patients is no longer a sporadic occurrence, and MRSA has become an endemic problem in many institutions (5). MRSA is most commonly introduced into an institution by an infected or colonized patient who serves as a reservoir and less commonly by a health care worker who disseminates the organism directly (6). Healthcare providers may

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become transient or persistent MRSA carriers. They may become a source of infection for patients as well as their own families (7). Mitsuda and colleagues demonstrated mother-to-infant transmission of *S. aureus*. The results showed that 7.5% of vaginal swabs from pregnant women and 10.1% of anterior nares swabs from the infants were positive for *S. aureus* (respectively 1.3% and 3.9% positive for MRSA strains in the anterior nares site). The prevalence of MRSA decreased with age (8, 9).

Resistance testing of hospital and patient microfloras is an important step in HI control (10). As recommended, patients being transferred from any centre with an outbreak or endemic problem due to MRSA, or patients with a colonized or infected family member, should be screened. It is discussed that an umbilical swab should be done in neonates (11).

Newborn's mortality in Lithuania decreased in 1994–1998 (Newborns health registration, 1996–1998). An active use of invasive procedures and treatment methods, antibiotics, and the increased number of patients having a decreased immunity lead to development of more resistant strains of microorganisms and respective diseases. On demonstrating the increasing incidence of MRSA among infected newborns, an analysis of *S. aureus* from newborn infants, delivered mothers and health care workers was assessed. The main aim of the present investigation was to determine significant risk factors for colonization with MRSA and MSSA strains in newborn infants.

MATERIALS AND METHODS

S. aureus colonization was tested at Kaunas Medical University Neonatology Clinic: in the Department for Preterm Newborns (DPN) and Neonatal Intensive Care Unit (NICU). All newborns born in KMU Obstetric and Gynaecology Clinic and admitted from regional hospitals were tested. To remove the probable seasonal effect on colonization rate, the tests were made in four periods: spring, summer, autumn and winter. Each period lasted 1–1.5 months.

Staphylococcal colonization rate (CR) was tested in 295 newborns (167 were treated in DPN and 128 in NICU) and in 205 delivered mothers. Medical personnel was assessed once during every period: first period – 48 members, second – 42, third – 47 and fourth – 50.

Clinical data on the assessed newborns were collected into a questionnaire. They included gestational age, birth weight, newborn's evaluation by APGAR scale, the length of antibiotic therapy. Data of anamnesis of delivered mothers were collected also. All newborn infants were classified by birth

weight into three groups: birth weight less than 1500 g, 1500–2500 g, and more than 2500 g (R. P. Gaynes, Center for Disease Control, 1991).

Microbiological samples were taken from anterior nares with sterile tampons into Stewart medium for transportation on the first day of arrival and on the day of departure of a newborn infant. Delivered mothers were examined before the first contact with the baby and medical personnel once per month three times in different periods (spring–summer, autumn–winter, winter–spring). All samples examined at the Microbiology Laboratory of Kaunas University Hospital.

Minimal inhibitory concentrations (MIC) to penicillin, methicillin, gentamycin, erythromycin and clindamycin were established after microbiological identification (12).

Statistical analysis was performed using the SPSS program package (*Statistical Package for Social Sciences*) 8.0 for Windows. We calculated the colonization rate (%), arithmetical means of quantitative parameters and χ^2 criterion of qualitative parameters of the assessed newborns, mothers and medical staff.

The relation between the length of antibiotic therapy and *S. aureus* colonization rate was determined using the nonparametric factorial Kruskal–Wallis analysis. Hotelling T criterion was applied for evaluation of the influence of birth weight and gestational age on colonization rate.

RESULTS

The majority of assessed newborns were preterm: 28.1% in the Department for Preterm Newborns and 71.1% in the Intensive Care Unit. Without hypoxia were born 59.7% of newborns. Caesarean section was made for 27.1% of newborns (Table 1).

Clinical characteristics	DPN	NICU
Gender:		
female (abs/%)	83(49.7)	75(58.6)
male (abs/%)	84(50.3)	53(41.4)
Gestational age:		
<37 wk (abs/%)	47(28.1)	91(71.1)
>37 wk (abs/%)	120(71.9)	37(28.9)
Mode of delivery:		
by natural ways (abs/%)	125(74.9)	90(70.3)
by cesarean section (abs/%)	42(25.1)	38(29.7)
APGAR scores:		
<7 (abs/%)	29(17.4)	90(70.3)
>7 (abs/%)	138(82.6)	38(29.7)
Total	167	128

Table 2. Means of some clinical signs of assessed newborns

Clinical signs	DPN	NICU
Length of hospitalization (days):		
mean	6.5	10.6*
minimum	1.0	0.0
maximum	64.0	60.0
95% PI	0.8	2.1
Gestational age (weeks):		
mean	37.8	32.9•
95% PI	0.4	0.9
Birth weight (grams):		
mean	3136.0	2124.5°
95% PI	117	174

*• °p < 0.05, compared with means of clinical signs of newborns in treated DPN

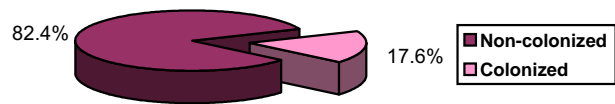


Fig. 1. *S. aureus* colonization rate of delivered mothers

colonized mothers were colonized 14.4% (p < 0.05). CR of newborns that had no contact with mothers was 35.3% (p < 0.05 compared with CR of newborns that were in contact with non-colonized mothers). CR of newborns that were in contact with non-colonized mothers or had any contact with delivered mothers was 16.9% (p < 0.05 compared with CR of newborns that were in close contact with *S. aureus* colonized mothers).

Means of some clinical signs of assessed newborns are shown in Table 2. The mean of the length of hospitalization time of newborns treated in DPN was 6.5 days, in NICU 10.6 days (p < 0.05). There was a significant difference between means of gestational age and birth weight of newborns treated in two different departments. Therefore the colonization-influencing factors were investigated in two separate groups.

S. aureus colonization rate

S. aureus colonization rate of newborns on the day of arrival to the Neonatology Clinic was 1.4%, on the day of departure 17.9% (p < 0.001). The CR of newborns treated in DPN was 1.4 times higher as compared to the CR of newborns treated in NICU.

The CR of delivered mothers was 17.6% (Fig. 1).

There was assessed the influence of contacts of delivered mothers with their newborns on the colonization rate. In DPN 150 newborns and in NICU 50 newborn infants (42.9%) were in close contact with mother (89.8%). The *S. aureus* colonization rate of newborns treated in DPN was increased by a close contact with *S. aureus* colonized mothers. In this case CR was 40% (Table 3). Newborns that were in contact with non-

Table 3. S. aureus colonization rate of newborns in relation to contact with mothers

Department	Newborns	Contact with mother			p
		Yes		No	
		Colonized mothers (abs./%)	Non colonized mothers (abs./%)		
DPN	Non-colonized (abs./%)	15(60.0)	107(85.6)	11(64.7)	0.004
	Colonized (abs./%)	10(40.0) •	18(14.4) °	6(35.3)* °	
Total:		25(100)	125(100)	17(100)	
NICU	Non-colonized (abs./%)	8(72.7)	35(79.5)	66(90.4)	0.133
	Colonized (abs./%)	3(27.3)	9(20.5)	7(9.6)	
Total:	11(100)	44(100)	73(100)		

•*p < 0.05 compared to CR of newborns that had a contact with non-colonized mothers.

°p < 0.05 compared to CR of newborns that had contact with colonized mothers.

Colonization with MRSA and MSSA strains

Newborns treated in NICU were colonized with MRSA more frequently than newborns treated in DPN (Table 4). Nine newborns colonized with MRSA strains were treated in NICU and three in DPN (p < 0.05).

We assessed the influence of contacts with delivered mothers and personnel on newborn CR in two cluster groups. Only one newborn colonized with MRSA strains had a close contact with mother. This mother was colonized with MSSA strains. Of all new-

Table 4. CR of newborns with methicillin-sensitive (MSSA) and methicillin resistant (MRSA) *S. aureus* strains in DPN and NICU

Department	Colonized newborns (abs./%)		Non-colonized newborns	Total (abs./%)	p
	MSSA	MRSA			
DPN	31(18.5)	3(1.8)	133(79.6)	167(100)	0.02
NICU	10(7.8)	9(7.0)*	109(85.2)	128(100)	

*p < 0.05 compared with CR of newborns treated in DPN.

borns, 91.67% had no contacts with mothers. Therefore MRSA strains could spread from the medical personnel.

Colonization rate in newborns treated with antibiotics was 11.6% and in not treated 21.9% (p < 0.05). Relation of CR to MRSA and MSSA strains and the length of treatment with antibiotics are shown in Table 5.

Table 5. Relation of CR to MRSA and MSSA strains and treatment with antibiotics in different departments

Newborns (abs./%)	Length of antibiotictherapy (days)			p
	<3 days	3-7 days	>7 days	
Non-colonized	167(79.9)	46(90.2)	29(87.9)	0.07
Colonized with MSSA strains	37(17.7)	2(3.9)	2(6.1)	
Colonized with MRSA strains	7(3.3)	3(5.8)	2(6.1)	
Total	211(100)	51(100)	33(100)	

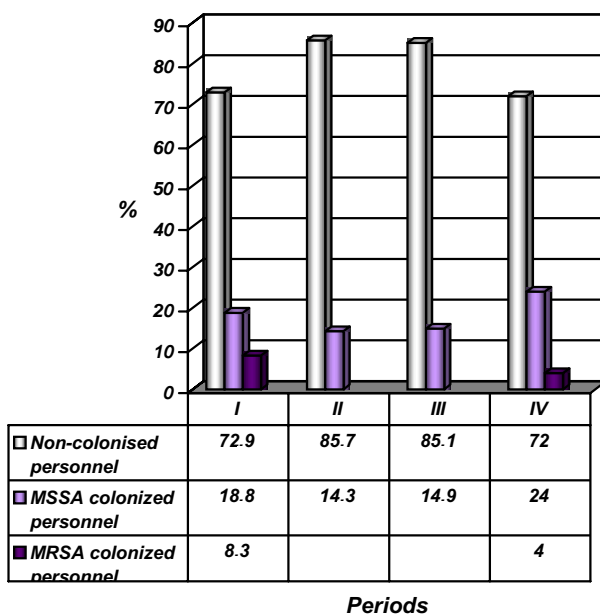


Fig. 2. Personnel *S. aureus* CR

The length of the treatment with antibiotics was higher among newborns colonized with MRSA strains.

We studied *S. aureus* colonization rate of medical staff.

The personnel CR was found to be higher in spring – summer period. In this period were identified MRSA strains. *S. aureus* colonization rate of the personell is shown in Fig. 2.

DISCUSSION

Different microorganism species colonize the newborn’s organism according to host’s tissues till a complex ecosystem develops, known as the normal adult human microflora (15).

Newborns admitted to high risk nurseries have impaired defenses against potentially pathogenic microorganisms. *S. aureus* colonizes the anterior nares of more than 50% of young infants (16, 17). This may be partly due to the humoral and cellular deficits and lower colonization defence capacity of newborn’s skin (12). The results provide evidence that a non-specific immunologic immaturity at birth is a risk factor for early bacterial colonization (18).

Due to the lack of simple and effective typing systems, colonization of newborns with different bacteria has rarely been studied.

S. aureus colonization of children without identifiable risk factors, according to Suggs et al. was 26.4%. In the present study we have demonstrated the influence of some risk factors contributing to the spread of *S. aureus* strains. About 18% of newborns treated in Neonatology Clinic were colonized with *S. aureus* on the day of departure from the hospital. Blackwell et al. and Harrison et al. have reported that nasal carriage of *S. aureus* is maximal in the perinatal period and decreases thereafter (13, 14). The study of Hayakawa T et al. determined that infants colonized with MRSA on the fifth day of life remained MRSA-positive 10 months after the outbreak (20).

Methicillin-resistant *S. aureus* (MRSA) infection in infants and neonates has become a serious concern not only in high-risk neonatal intensive care units, but also in general nurseries. In the study of Suggs et al. it was shown that 8.3% of children colonized with *S. aureus* strains were MRSA carriers and 36.4% of the 11 subjects (colonized with MRSA) had no risk factors (19). According to our data, staphylococcal colonization rate was significantly higher among newborns treated in DPN than those treated in NICU. The results differ according to MRSA strains. Newborn colonization with resistant *S. aureus* strains was 7.0% in NICU versus 1.8% in DPN,

possibly because of the lower maturity of preterm newborns and a more frequent use of antibiotics in the NICU. It is not exactly known which factor influences the development of staphylococcal infection more often: the use of broad spectrum antibiotics, instrumental procedures, increased number of extremely ill patients or "personnel-to-personnel" transmission. It is possible that all these factors work together most of the time (15).

Mother's colonization rate with staphylococcus reached 17.6%. Analysis of the effects of the mother's contacts with the newborn showed that newborns that were in contact with *S. aureus* colonized mothers were more frequently colonized with staphylococcus than those who were not nursed by their mothers or nursed by non-colonized mothers. The effect of medical personnel contacts on newborn colonization (in this group newborns had no contact with their mothers) was statistically higher than in the group where nursing mothers were not colonized.

Literature data show that mothers' colonization with different staphylococcal types is not the same. The colonization can vary between 1.9% to 25%. According to Dancer, during pregnancy colonization reaches 33% (nose 61%, perineal region 25%, axillary region 2%) (19, 21).

Our analysis showed that 22.6% of *S. aureus* strains colonizing newborns were resistant to methicillin. Eleven from 12 newborns colonized by MRSA had no contact with mothers. One newborn was nursed by his mother who had methicillin-sensitive *S. aureus*. This led to the hypothesis that all MRSA-colonized newborns had a hospital source of infection through horizontal transmission from *S. aureus* colonized medical personnel. Control of the outbreaks of MRSA in the NICU was achieved by isolation and cohorting of patients and strict adherence to prescribed policies and procedures.

Thus, *S. aureus* colonization rate was higher among newborns in the department for preterm babies than in Neonatal Intensive Care Unit. *S. aureus* colonization rate was higher among newborns whose hospitalization time was longer, newborns who were in close contact with *S. aureus* colonized mothers and were not breastfed.

Newborns in Neonatal Intensive Care Unit were colonized more frequently with MRSA strains than in Department for Preterm Neonates.

Resistant *S. aureus* strains spread through medical personnel, because newborns colonized with resistant *S. aureus* strains were not in contact with mothers. Newborns and medical personnel were colonized with antibiotic-resistant *S. aureus* strains.

The risk of hospital-acquired infections can be lowered by hygienic procedures in neonatal nur-

series and limitation of the length of antibiotic therapy.

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S. AUREUS KOLONIZACIJA LEMIANTYMS VEIKSNIAI NAUJAGIMIŲ SKYRIUOSE

S a n t r a u k a

Naujagimystė yra ypač svarbi tolimesniam vaikų vystymuisi, nes ankstyvuojų adaptacijos laikotarpiu vyksta naujagimių kolonizacija įvairiais mikroorganizmais. Pagrindiniai *S. aureus* padermių šaltiniai yra užkrėsti ar kolonizuoti šiuo infekcijų sukėlėju pacientai, medicinos personalas, naujagimius slaugančios motinos. Pagrindinis šio darbo tikslas buvo ištirti *S. aureus* padermių transmisiją bei kolonizaciją lemiančius veiksnius naujagimių skyriuose (tarp gydytų naujagimių, personalo ir motinų) naudojant statistinės analizės metodus. Nustatėme, kad naujagimių, gydytų Naujagimių ankstyvos patologijos skyriuje, kolonizacija *S. aureus* padermėmis didėjo, kai ilgėjo gydymo trukmė, naujagimius slaugė stafilokokais kolonizuotos motinos, jie nebuvo žinomi. Gydymas antibiotikais mažino naujagimių *S. aureus* kolonizacijos dažnumą abiejuose skyriuose. Atsparios antibiotikams *S. aureus* padermės plinta per kontaktą su medicinos personalu.

Raktažodžiai: naujagimis, kolonizacija, *S.aureus* padermės, atsparumas meticilinui