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Prospective surveillance of bacterial colonization and primary sepsis: findings of a tertiary neonatal intensive and intermediate care unit

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SUMMARY

Background: Preterm infants and critically ill neonates are predisposed to nosocomial infections as sepsis. Moreover, these infants acquire commensal bacteria, which might become potentially harmful. On-ward transmission of these bacteria can cause outbreaks.
Aim: To report the findings of a prospective surveillance of bacterial colonization and primary sepsis in preterm infants and neonates.
Methods: The results of the surveillance of bacterial colonization of the gut and the respiratory tract, targeting meticillin-resistant *Staphylococcus aureus* (MRSA), vancomycin-resistant enterococci (VRE) and Gram-negative bacteria from November 2016 to March 2018 were analysed. Bacterial colonization was compared to surveillance of sepsis.
Findings: Six-hundred and seventy-one patients were admitted and 87.0 % (*N*=584) of the patients were screened; 48.3% (*N*=282) of the patients screened were colonized with at least one of the bacteria included in the screening; 26.2% of them (*N*=74) had multi-drug-resistant strains. A total of 534 bacterial isolates were found. The most frequently found species were *Escherichia coli*, *Enterobacter cloacae*, *Klebsiella oxytoca* and *Klebsiella pneumoniae*. Three MRSA but no VRE were detected. The surveillance detected a *K. pneumoniae* cluster involving nine patients. There were 23 blood-culture-confirmed sepsis episodes; 60.9% (*N*=14) were caused by staphylococci. Gram-negative bacteria (one *Klebsiella aerogenes* and two *E. cloacae*) caused three sepsis episodes which were preceded by colonization with the respective isolates.
Conclusions: Surveillance of colonization provided a comprehensive overview of species and antibiotic resistance patterns. It allowed early detection of a colonization cluster. Knowledge of colonization and surveillance of sepsis is useful for guiding infection control measures and antibiotic treatment.

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Introduction

Preterm infants and critically ill neonates are at high risk for late-onset (nosocomial) sepsis, due to their immature immune system, ineffective mucosal barriers and the need of invasive devices [1–5]. The risk of late-onset sepsis increases with lower birthweight and lower gestational age. The gut of preterm infants has been identified as a reservoir of potential pathogens from where bacterial translocation might lead to bloodstream infection [6,7]. Preterm infants show an altered spectrum of colonizing microorganisms in comparison to healthy term-born infants [8]. Their gut microbiome may acquire Enterobacterales or multi-drug-resistant bacteria from the neonatal ward [9–11]. Bacterial colonization of preterm infants and hospitalized neonates may take place via healthcare workers, parents, other children hospitalized on the ward or the inanimate environment [12–15]. Several factors, such as mode of birth, type of nutrition and antibiotic treatment, are known to influence the developing microbiome in neonates [16–19]. Some bacterial organisms such as *Serratia marcescens* and *Klebsiella pneumoniae*, that are potentially harmful pathogens, have been reported to cause outbreaks on neonatal wards [20,21]. To address these challenges, neonatal wards need to follow strict infection-control principles. In some countries normative directives exist and therefore certain infection control activities are mandatory. In Germany a prospective and standardized surveillance of nosocomial infections including sepsis, pneumonia and necrotizing enterocolitis is required for tertiary care neonatal intensive care units. Moreover, in Germany, general colonization screening that targets Gram-negative and selected Gram-positive bacteria has been recommended for preterm infants with a very low birthweight (VLBW) of less than 1500 g.

In the following, the results of the surveillance of colonization and sepsis at our neonatal ward and their implications for infection control guidance are presented and discussed.

Methods

Setting and basic infection-control measures

Our neonatal ward meets the requirements of a tertiary referral centre and provides intensive and intermediate care (NICU and IMC) for preterm infants and severely ill neonates. The NICU section offers 10 intensive care incubators in three neighbouring rooms (two rooms with four incubators and one room with two incubators). Intermediate care is provided in five other rooms on the same ward equipped with 14 beds overall. Seven neonatologists, four consultants, six residents and 54 specialized nurses are involved in primary patient care.

Daily disinfection of equipment, surrounding surfaces and the floor was performed with commercial bactericidal chemical agents containing either alcohol, quaternary ammonium compounds (QAC) or a combination of alcohol with QAC and an aliphatic amine. Neonates were put into a new incubator every week. After usage, incubators were disinfected with a sporicidal agent containing active oxygen-releasing ingredients. Infants with colonization and/or infection with meticillin-resistant *Staphylococcus aureus* (MRSA), vancomycin-resistant enterococci (VRE), or with Gram-negative bacteria with resistance to carbapenems were isolated in rooms with one incubator (in these cases the remaining incubator/bed spaces in the room were not used). The same applied to patients with Gram-negative bacteria with concurrent resistance to piperacillin, cefotaxime/ceftazidime and ciprofloxacin. The nurse to patient ratio varied from 1:1 to 1:4 based on the patient's medical condition. Routine and on-demand training sessions and infection-control audits were performed for the medical staff by the infection-control unit. Parents were trained in standard precautions including hand hygiene. Kangarooing with the parents, a minimal handling approach, antibiotic stewardship efforts to limit antibiotic use, use of probiotics for preterm infants with a gestational age $<$28 weeks and/or a birthweight below 1000 g and the early feeding of mother milk were used to support the infant's development and to contribute to a 'natural' microbiome acquisition.

Surveillance of colonization

Screening was recommended for all patients on admission. In addition, a continuous screening of all infants with a weight of less than 1500 g and those that required intensive care was recommended once a week. For that, a nasopharyngeal swab and a rectal swab were taken from each patient. An additional specimen from the respiratory tract was taken from intubated patients on a ventilator. The screening targeted MRSA, VRE and selected Gram-negative bacteria, i.e. members of the order Enterobacterales (including the genera *Escherichia, Klebsiella, Citrobacter* or *Enterobacter*), *Pseudomonas aeruginosa* and *Acinetobacter species*.

Surveillance of nosocomial sepsis and hand hygiene compliance

In all VLBW infants, surveillance of nosocomial primary sepsis took place according to the criteria published by the German National Reference Centre for Surveillance of Nosocomial Infections (NRZ) for preterm infants (NEO surveillance). The surveillance was carried out until death, discharge from the ward or until the patients weighed more than 1800 g [22]. In addition, for all other infants and VLBW infants weighing more than 1800 g, surveillance of primary nosocomial sepsis was performed until discharge or death according to standard criteria also published by the NRZ (standard sepsis surveillance). This surveillance was based basically on the well-established Centers for Disease Control and Prevention definitions for primary bloodstream infection. In this study, only blood-culture-confirmed sepsis cases (microbiology confirmed primary bloodstream infections) were included. In brief, for a diagnosis of confirmed sepsis NEO sepsis surveillance required one positive blood culture together with clinical and laboratory parameters of infection. Standard sepsis surveillance required solely a positive blood culture, except in the presence of typical skin commensals as *Staphylococcus epidermidis*. In that case, two independent positive blood cultures and at least one clinical parameter of infection had to be verified. Sepsis-related death was defined as death occurring within seven days of a positive culture and no explanation other than sepsis.

Hand hygiene compliance was monitored by direct observation [23] and performed by the infection-control staff regularly once per year and unscheduled on special occasions such as suspected clusters.

Table I
Results of surveillance of bacterial colonization with respect to Gram-negative bacteria (November 2016 to March 2018)

Species	Number of patients with this species	Number of bacterial strains				Total number of bacterial strains
		Gram-negative bacteria resistant to				
		*	Piperacillin and cefotaxime/ceftazidime	Piperacillin, cefotaxime/ceftazidime and ciprofloxacin	Piperacillin, cefotaxime/ceftazidime and meropenem/imipenem	
Acinetobacter baumannii	11	11 (intrinsic resistance)		0	0	11
Other *Acinetobacter sp.*	5	Antimicrobial susceptibility testing was not done				5
Citrobacter freundii	21	19	3	0	1	23
Other *Citrobacter sp.*	14	12	2	0	0	14
Enterobacter cloacae	105	90	30	1	0	121
Other *Enterobacter sp.*	20	16	4	0	0	20
Escherichia coli	131	124	8	2	0	134
Other Escherichia sp.	4	4	0	0	0	4
Klebsiella aerogenes	29	5	25	0	2	32
Klebsiella oxytoca	72	71	2	0	0	73
Klebsiella pneumoniae	49	48	1	1	1	51
Morganella morgagnii	4	3	1	0	0	4
Pseudomonas aeruginosa	2	1	1	0	0	2
Serratia marcescens	3	3	0	0	0	3
Other *Enterobacterales*	32	31	3	0	0	34

The sum of patient numbers in this table is higher than 282 as some patients acquired more than one bacterial species (same applies for the patients with multidrug resistant bacteria). The total number of bacterial strains can be higher than the total number of patients with the respective species, as some patients may have two or more different strains (based on the resistance pattern) of the same species.
* No special resistance.

Microbiological cultures

Screening swabs were cultured on MRSA- and VRE-selective agar plates (Brilliance MRSA 2 AGAR and Brilliance VRE Agar, Thermo Fisher Scientific, Waltham, MA, USA) and on locally produced MacConkey Agar (without antibiotic supplementation against Gram-negative bacteria). Antimicrobial susceptibility testing was performed with the VITEK® 2 (bioMérieux, Marcy-l'Étoile, France) or Merlin system (Merlin Diagnostika, Bornheim-Hesel, Germany). Inspired by established definitions of antibiotic multi-drug resistance in Germany, Gram-negative isolates were defined in our study as multi-drug resistant with resistance against (1) piperacillin and cefotaxime/ceftazidime, (2) piperacillin, cefotaxime/ceftazidime and ciprofloxacin or (3) piperacillin, cefotaxime/ceftazidime and meropenem/imipenem [24]. Those isolates, as well as MRSA and VRE, were regarded as multi-drug-resistant bacteria. Screening results were obtained from the institute's laboratory information system. The number of patients was provided by the hospital administration. Duplication of results was avoided by copy strain elimination (i.e. strains of the same species with identical antibiotic susceptibility pattern from different sampling locations at the same time point, e.g. rectal and pharyngeal, or repeated findings at different time points in the observation period).

For molecular typing of bacterial isolates, pulsed-field gel electrophoresis (PFGE) was performed (1% agarose gel, restriction enzyme Xba I for *Klebsiella sp.* isolates). Molecular relationship of bacterial strains was evaluated visually based on the criteria described by Tenover et al. [25].

Environmental sampling of surfaces with standard swabs and contact plates (Tryptone Soya Agar with disinhibitor; Oxoid, Wesel, Germany) was performed on occasion (e.g. suspected cluster).

Results

Surveillance of colonization

From November 2016 to March 2018, a total of 671 patients were treated on the ward and 87.0% (N=584) of these were screened. Overall 2960 screening samples were collected (i.e. on average five screening samples per patient). At least one of the bacteria targeted by the colonization surveillance was found in 48.3% (N=282) of the patients screened. Of these 46.5% (N=131) were colonized with *E. coli*, 37.2% (N=105) with *Enterobacter cloacae*, 25.5% (N=72) with *K. oxytoca*, 17.4% (N=49) with *K. pneumoniae*, 1.1% (N=3) with *S. marcescens* and 0.7% (N=2) with *P. aeruginosa*. Multidrug resistant bacteria were found in 26.2% (N=74) of the 282 colonized patients.

Overall, 534 different bacterial strains were detected (copy strains excluded), adding up to an average of 1.9 strains per colonized patient. Only three isolates (0.6%) were Gram-positive bacteria (all MRSA) with the majority of isolates (99.4%, N=531) being Gram-negative. An overview of the Gram-negative bacteria identified is given in Table I.

Of the 531 Gram-negative bacteria 16.6% (N=88) were multidrug resistant. Of these, 90.9% (N=80) showed resistance to piperacillin and cefotaxime/ceftazidime. Four isolates each (4.5%) showed resistance to piperacillin, cefotaxime/ceftazidime and ciprofloxacin (one *E. cloacae*, two *Escherichia coli and* one *K. pneumoniae*) or resistance to piperacillin, cefotaxime/ceftazidime and meropenem/imipenem (one

Citrobacter freundii, two *Klebsiella aerogenes* and one *K. pneumoniae*), respectively.

Of the *K. pneumoniae* strains, nine were detected as part of a monoclonal colonization cluster.

Surveillance of nosocomial sepsis

All patients (*N*=671) were monitored for sepsis according to standard sepsis surveillance guidelines. Of these, 146 patients were eligible for NEO surveillance (VLBW infants). Altogether 23 culture-confirmed sepsis episodes were diagnosed in 21 patients (two patients each had two episodes). All 23 sepsis episodes were late-onset infections. Fifteen of the sepsis episodes occurred in the VLBW infant cohort (NEO surveillance). One of these 15 bloodstream infections in VLBW infants was caused by *K. aerogenes* with resistance to piperacillin and cefotaxime/ceftazidime that had already been detected in the surveillance of colonization before the onset of sepsis. The pathogens of the other 14 sepsis episodes were not targeted by the screening. They included nine coagulase-negative staphylococci, two methicillin-susceptible *S. aureus* (MSSA) and three *Bacillus cereus*.

Two of the eight sepsis episodes that occurred in the infants of the standard sepsis surveillance cohort were caused by a pathogen that had been detected in the surveillance of colonization before the onset of sepsis (*E. cloacae* without multidrug resistance in both cases). The other six episodes were caused by MSSA (*N*=2), *Enterococcus faecalis* (*N*=1), *Enterococcus faecium* (*N*=1) and *Candida albicans* (*N*=1). One sepsis episode was caused by MRSA. In that case, screening samples prior to sepsis were all negative for MRSA but colonization with MRSA was only found after the onset of sepsis.

Nosocomial K. pneumoniae colonization cluster

Over a period of three weeks in April and May 2017, the colonization screening detected nine patients with hospital-acquired rectal and/or pharyngeal colonization with *K. pneumoniae*. Invasive infections of *K. pneumoniae* (e.g. bloodstream infection) were not observed in these patients. The mean duration from admission to the ward to the first positive screening sample was 35 days (range 5–89 days). Among the nine patients were two sets of twins.

All nine isolates showed an identical phenotypic resistance pattern with an unusual low minimal inhibitory concentration for ampicillin and no other resistance. In five of the nine patients the *K. pneumoniae* isolates were available for molecular typing by PFGE. According to the criteria published by Tenover et al., the strains were indistinguishable (Figure 1), suggesting on-ward transmission resulting in a monoclonal spread.

In order to stop transmissions of the *K. pneumoniae* strain among patients several additional infection-control measures were established (Table II), which proved effective. After full implementation no further colonization with this strain was detected. The additional measures were kept up until the last of the affected patients was discharged from the ward in June 2017.

Discussion

In the present article the results of a prospective surveillance of bacterial colonization and nosocomial sepsis in patients treated on the NICU and IMC unit at Hannover Medical School are reported. Colonization screening of infants treated on an NICU is publicly recommended and widely practiced in Germany [26]. However, the duration of the screening is not specified. In our centre the screening is discontinued once the infants weigh more than 1500 g, unless further intensive care is required, as infants requiring intensive care are at high risk of late-onset sepsis. Other units use an extended screening schedule, which is continued until discharge of the patient [26].

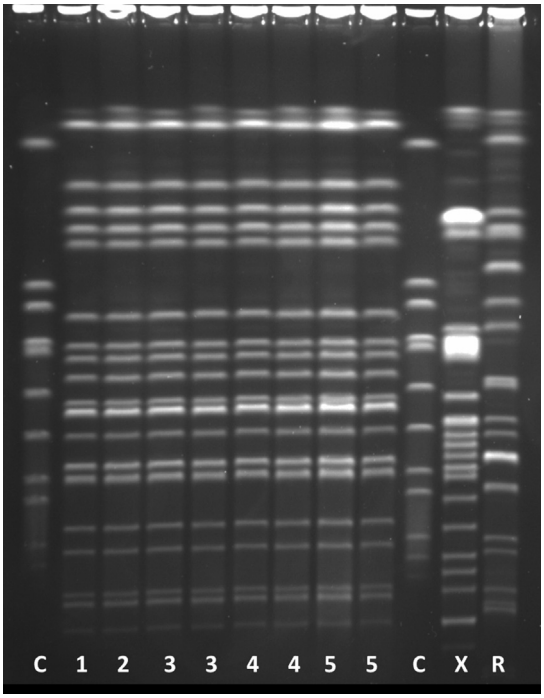

Figure 1. Pulsed-field gel electrophoresis of the available *Klebsiella pneumoniae* outbreak strains. C= *Staphylococcus aureus* control strain NCTC® 8325. R= *Klebsiella pneumoniae* reference strain ATCC® 700603. 1–5= five patients showing the identical pulsotype (monoclonal pattern). For patients 3 to 5, two bacterial isolates were available and examined each. X = *Klebsiella pneumoniae* strain not belonging to the suspected cluster.

The colonization screening was especially designed to detect Gram-negative bacilli from the order Enterobacterales (e.g. the genera *Klebsiella*, *Enterobacter* and *Citrobacter*) or non-fermentative bacteria such as *Acinetobacter species* and *P. aeruginosa*, which are known to be potentially harmful for preterm infants and have the potential to cause outbreaks. Except for MRSA and VRE, Gram-positive bacteria were not targeted by the screening. During the study period our screening identified three patients with MRSA colonization, which is in line with findings from another German neonatology ward (with intermediate and intensive care) that also reported only small numbers of MRSA (i.e. four cases in two years) [27]. A survey from Japan also showed a decreasing overall prevalence of MRSA in several NICUs [28]. Nonetheless, the impact of MRSA is still relevant in NICUs and outbreaks have been reported [29]. VRE were not detected during the entire study period. Outbreaks with VRE have been described in NICUs, with environmental contamination seeming to be especially important for transmission [30]. In a Spanish study, *E. faecalis* and

Table II
Klebsiella pneumoniae cluster control measures

Convening of a cluster control team consisting of leading physicians and nurses as well as infection control staff.
Strict isolation and cohorting of the affected patients in separate rooms on the ward.
Barrier precautions for healthcare workers during direct patient care in affected patients (gloves and gown).
Repeated audits and feedback talks on the ward by the infection control staff targeting basic precautions and hand hygiene compliance
Enhanced cleaning and disinfection.
Colonization screening was increased from once to twice weekly.
Environmental screening (immediate patient surrounding in rooms of affected and non-affected patient, commonly used medical and nursing equipment such as sonography equipment, linen, incubators, etc.) and microbiological examination of disinfection solution (results: all tests negative).
Strict usage of healthcare products such as stethoscopes or body care utensils for one patient only.
Ad hoc hand hygiene compliance evaluation by direct observation (result: overall compliance of about 85% among nursing and medical staff).

E. faecium were found in faecal samples of preterm infants [10]. However, vancomycin-sensitive enterococci were not explicitly looked for in screening specimens. At present, general screening for VRE or MRSA is not recommended for German NICUs.

Goldmann et al. already showed in the 1970s that 48% of 63 infants on am NICU in the United States had *E. coli* in their stools, whereas 52% were colonized with the genera *Klebsiella*, *Enterobacter* or *Citrobacter* [31], which is comparable with our findings. In Spain, Moles et al. reported *S. marcescens* colonization in nearly all preterm infants (96.2%, *N*=25) during a nine-month observation period between 2009 and 2010 [10]. Interestingly, in our study, only three patients acquired *S. marcescens* during the 15-month observational period. This emphasizes that microbial findings vary between NICUs. It is also noteworthy that only two patients with *P. aeruginosa* colonization were found. This might be due to several infection-control measures that were in place to minimize the risk for *P. aeruginosa* acquisition. All tap water supply points on the ward were equipped with sterile filters. Sterile filtered water was used for bathing of infants. Bathing bowls were sterilized after each use. Partition walls separated the basins in the patient rooms so that the risk for cross-transmission via splashing water from the sinks was minimized.

In our study, multi-drug-resistant bacteria were found in 12.7% (*N*=74) of the 584 neonates that were screened. Haase et al. reported in a study from another German University hospital that in 2011 and 2012 on average 4.9% out of 635 neonates were colonized with mostly Gram-negative multi-drug-resistant bacteria (2.3% in 2011 and 8.1% in 2012). In this study VRE, MRSA, and Gram-negative bacteria with extended-spectrum beta-lactamase or AMP-C resistance were considered multi-drug-resistant [27]. A study from Italy found that overall 28.8% of 1152 neonates were colonized with multi-drug-resistant Gram-negative bacteria over a period of 5 years; 20.6% in the first year (2009) and 35.9% in the last year (2014). In that study multi-drug-resistant Gram-negative bacteria were defined as being resistant against at least three groups of antibiotics (amoxicillin clavulanic acid, $3^{rd}/4^{th}$ generation cephalosporins, monobactams, aminoglycosides or carbapenems) [32]. A study from the Philippines reported 55% of 1831 neonates to be colonized with multi-drug-resistant Gram-negative bacteria, using cephalosporins and gentamicin as markers for antibiotic resistance [11]. In addition, in a smaller study from Ecuador, 56% of 73 neonates had beta-lactamase-producing Gram-negative bacteria in stool samples collected over three months [33]. In Germany the definition of multi-drug resistance combines resistance classes (including for instance third-generation cephalosporins, piperacillin and carbapenems) while internationally the concept of a single pathogen-resistance combination is often used.

The rather low rate of multi-drug-resistant bacteria on our ward may be explained by different factors. First, the ward implemented strict barrier and isolation precaution measures whenever a multidrug-resistant bacterium was detected, and second, antibiotic stewardship efforts aimed at reduction of antibiotic use on the ward in order to lower the risk for potential selection of resistant strains. Taken together, occurrence of multi-drug resistance shows regional and temporal differences and comparison is complicated by various definitions of resistance.

In terms of sepsis, Haase et al. reported 32 late-onset (nosocomial) sepsis cases in 635 neonates, which is comparable to our findings. Moreover, they reported that coagulase-negative staphylococci were the dominating species found in positive blood cultures in their patient cohort [27], which has also been shown in a Germany wide analysis including 4094 VLBW infants with culture confirmed, primary bloodstream infections [34]. However, in another study which took place in the United States the prevalence of coagulase-negative staphylococci as late-onset sepsis pathogens diminished over time continuously to 0% after several infection-control interventions took place [35].

Bacteria from the gut have been recognized as an important reservoir of bloodstream infection pathogens in preterm infants [6,7,36]. In a study from the US, Smith et al. identified 7.3% (*N*=51) of 698 infants with a sepsis episode caused by Gram-negative bacteria. Each of these events was preceded by a screening sample showing the same strain and antibiotic susceptibility [37]. The findings by Smith et al. suggested that targeted surveillance of colonization among preterm infants can be used to guide empiric antibiotic therapy for initial treatment of sepsis, especially as sepsis with Gram-negative bacteria is associated with a distinctly higher mortality rate than Gram-positive sepsis [35]. However, in a study by Nayar et al. at a British NICU, patients colonized with *P. aeruginosa* did not develop a subsequent infection with this bacterium [38]. In our study only three of the patients developed Gram-negative sepsis. Similar to Smith et al., each of these episodes was preceded by a positive screening sample showing the

identical Gram-negative isolate with the same antibiotic susceptibility pattern. Therefore, the initiated antibiotic therapy was guided by these screening results. Mortality of Gram-negative sepsis in our study was 0%, which might be attributable to guided antibiotic treatment. Nevertheless, numbers in this study were too low to allow a valid statement. Our empiric antibiotic therapy of suspected late-onset sepsis depended on the patient's condition. In the absence of a central venous catheter (CVC) a combination of ampicillin, cefotaxime and tobramycin was used, while cefotaxime and vancomycin were used when a CVC was present. In case of colonization with a Gram-negative rod with resistance to aminopenicillines and cephalosporins, a combination of vancomycin and meropenem was used. In general, empiric antibiotic treatment was modified, in particular restricted, corresponding to the results of the current microbiologic (blood culture) findings.

In our facility the surveillance system allowed the identification of a colonization cluster with *K. pneumoniae*, which occurred most likely due to on-ward transmission. *K. pneumoniae* is well-known to cause nosocomial infections in preterm infants and several outbreaks have been reported in recent years [39]. In order to avoid further transmissions, on our ward colonized patients were strictly isolated as a cohort as reported in *K. pneumoniae* outbreaks previously [20]. Repeated feedback talks and audits took place on the ward addressing hand hygiene and standard precautions. Unscheduled direct observations took place revealing a rather high compliance rate to hand hygiene of 85% among the medical staff. All environmental samples turned up negative making transmission via inanimate objects and surroundings unlikely. Nonetheless, further efforts were undertaken to enhance environmental cleaning, especially regarding the patient's immediate surroundings, which can be contaminated by the patient's microbiome [40]. Although reported in the literature [20], screening of medical staff or parents was not performed, but the potential carriage of parents and/or medical staff was addressed by focusing on high compliance to hand hygiene.

Our study has some limitations. (1) It is a single-centre study. Findings may therefore not be transferable to other institutions. However, the practices and findings described here might be helpful for infection-control management in other institutions. (2) The evaluation of transmission dynamics in the observation period is limited as weekly screening after admission addressed infants with a weight below 1500 g in general and those requiring intensive care, but not the other patients. However, the screening procedure was sensitive enough to detect a *K. pneumoniae* cluster. (3) Only blood-culture-positive sepsis was taken into account, which might lead to an underestimation of the true burden of nosocomial sepsis.

Prospective screening revealed that the genera *Escherichia, Enterobacter and Klebsiella* were the predominant Gram-negative colonization species on our ward. Multi-drug-resistant bacteria were found in 26.2 % of the colonized patients, which were almost exclusively Gram-negative bacteria with resistance to piperacillin and ceftazidime/cefotaxime. Surveillance of colonization allowed early detection and containment of a *K. pneumoniae* cluster, and can be used as an indicator for compliance with infection control standards. Moreover, it provides a comprehensive overview on species and antibiotic resistance patterns among colonizing bacteria on a neonatal ward. Sepsis was mainly caused by staphylococci in our study, but interestingly in each of the three Gram-negative sepsis episodes, colonization of the patient with the respective bacteria preceded the occurrence in the bloodstream. Taken together, surveillance of colonization and sepsis helps to identify clusters of colonization for the timely initiation of transmission control measures. Furthermore, it provides guidance for infection control measures and may help to choose empiric antibiotic treatment.

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Conflict of interest statement

The authors declare that they have no competing interests.

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