Early umbilical bacterial colonization in relation to blood culture in neonates admitted to two neonatal intensive care units in Khartoum City, Sudan

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ABSTRACT

Background: Umbilical colonization has long been used as an indicator of early neonatal infections. Factors related to the mother, baby or the environment has been involved in the acquirement of colonizers and even developing neonatal sepsis later on. This study aimed to assess the relation between early umbilical bacterial colonization and blood culture in neonates admitted to two Neonatal Intensive Care Units in Khartoum City, Sudan.

Materials and Methods: Eighty neonates suspected to have sepsis were included in the study. Umbilical swabs were taken in the first twelve hours of life and were sent for culture. The results were then compared to the results of blood cultures to find if there was any matching between the grown organisms. Neonates' and mothers' information were obtained by an interview and documented in data collection sheets.

Results: Umbilical colonization was present in 20% (n=16) of the study population while 21.25% (n=17) had positive blood cultures. Of the colonized group, *Staphylococcus aureus* was the commonest organism isolated (n=6, 37.5%), followed by *Pseudomonas spp.* (n=3, 18.8%) and *Klebsiella spp.* (n=2, 12.5%). While in those with positive blood culture *Pseudomonas spp.* predominated (n=7, 41.2%).followed by *klebsiella spp.* (n=5, 29.4%) and *Staphylococcus aureus* (n=3, 17.6%); 58.8% (n=47) of the patients had no growth in swabs or blood cultures, while positive results showed no matching (p value=0.009).

Conclusion: Umbilical swab culture had a negative predictive value of 81% for early neonatal (blood culture positive) infection, 36% positive predictive value, specificity of 84% and sensitivity of 31%. Therefore, in this study umbilical swab culture was a poor indicator for bacteraemia (sepsis) in the newborn.

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INTRODUCTION

Postpartum infections are important causes of neonatal morbidity and mortality, worldwide. A high percentage of these infections may originate from bacterial colonization of the umbilicus; as the necrotic tissues of the umbilical cord serve as favorable places for bacterial colonization established shortly after birth[1,2]. The skin of the newborn ''including the umbilical stump'' is colonized soon after birth by both pathogenic and non-pathogenic microorganisms. The profile of organisms colonizing the cord stump varies according to hygienic conditions at the time of birth and immediate postpartum period[3]. The overall proportion of mortality related to local umbilical cord infections that become systemic is unknown, but exposure to pathogens with or without the development of local signs of umbilical stump infection (omphalitis) is thought to be an important event in the pathway to sepsis and death in newborns[4]. Sources of potentially pathogenic

bacteria that colonize the umbilical cord include the mother's birth canal and surroundings at the site of delivery, most prominently the non-sterile hands of any person assisting in the delivery[1].

Microorganisms could be acquired by the neonate from the mother before or during birth (vertically transmitted or perinatally acquired). These commonly cause early onset neonatal sepsis[5]. They also could be acquired from the environment i.e. nosocomial and horizontally transmitted. The latter contributes to infections presenting after seven days of birth (late onset sepsis)[5]. The most frequently reported organism to colonize the umbilical cord is *Staphylococcus aureus*. Other common pathogens include group A and group B Streptococci and Gram-negative bacilli including *Escherichia coli, Klebsiella spp. and Pseudomonas spp*. rarely, anaerobic and polymicrobial infections also may occur. In addition to omphalitis, tetanus in neonates can result from umbilical cord colonization, particularly in countries with limited resources[1]. The most common organism isolated from both maternal genital tract and surface cultures of babies was *Escherichia coli,* while *Klebsiella spp*. is the most common organism isolated from blood[5].

Bacterial colonization does not always result in disease. Factors influencing which colonized infant will experience disease are not well understood, but include: prematurity, underlying illness, invasive procedures, inoculums size and virulence of the infecting organism, genetic predisposition, the innate immune system, host response and trans-placental maternal antibodies[6].

It is well known that neonatal infections are contributing significantly to neonatal morbidity and mortality in developing countries and that umbilical colonization is one of the predisposing factors for these infections. As a health care team that works in a developing country, we need to focus more on studies that help in the assessment of the predisposing factors for infections; so as to come out with measures to reduce them. This study aimed to assess the relation between early umbilical bacterial colonization (i.e. colonization that occurs within the first 12 hours of life) and blood culture in neonates admitted in two neonatal intensive care units in Khartoum City, Sudan.

MATERIALS AND METHODS

This was a prospective cross-sectional hospital based study, performed in the neonatal intensive care units (NICU) of Soba University Hospital (SUH) and Saad Abul-ella Teaching Hospital (SATH) in Khartoum City, Sudan, from: June 2019 to January 2020. The study targeted a) all neonates admitted to the NICU and who were planned to have blood taken for culture on day one of life according to the suspicion of having sepsis and decision of the admitting doctor and b) neonates who were kept beside their mothers from whom blood cultures were also planned to be taken on day one before starting antibiotics. The study excluded neonates with umbilical or anterior abdominal wall malformations and those whose parents did not give consent.

The sample size was calculated according to the formula: $n= z^2*P (1-P)/ d^2$ [31]**,** where (n) is the sample size, (Z) is the statistic corresponding to level of confidence (1.96, confidence interval 95%), (P) is the expected prevalence (0.073)[32], and (d) is the precision (corresponding to effect size) (= 0.06). Calculated sample size was 72, and a total of 80 patients were included in the study. The neonates meeting the criteria were selected by simple random sampling.

Data was collected by interviewing the mothers and also from maternal, neonatal as well as from the laboratory records. Umbilical swabs were taken within the first 12 hours after birth (the mean time of sampling was 6.19 hours ± 3.307, range: 1-12 hours) using sterile swab sticks, from the tip, along the shaft and from the base of the umbilical stump. Before taking the sample, hand washing using soap and then rubbing with an antiseptic was ensured. (The umbilical stump had only been treated by dry cord care). The swabs were then taken directly for microbiology without using transport media.

Culture and sensitivity were performed in Mac Conkey and blood agar. Organisms were identified and antibiotic sensitivity was tested. Blood cultures were also taken using sterile procedure. The final result was then checked ''after seven days" and compared to the result of the umbilical swab culture ''which had taken three days".

The collected data were analyzed using Statistical Package for Social Sciences (SPSS) version 22. The association between different variables was studied using Chi Square test with a level of significance $p< 0.05$. Ethical approval was obtained from the Ethical Committee, Sudan Medical Specialization Board and Council of Paediatrics and Child Health. Permission was granted from the hospital administrators as well as heads of departments of the NICU and microbiology. Informed written consents were also obtained from the caregivers of the patients.

RESULTS

Of the 80 patients studied, 55% (n=44) and 45% (n=36) were admitted to SUH and SATH, respectively and 55% (n=44) were males. The gestational age was between 37-40 weeks in 52.5% (n=42) and in 20% (n=16), 17.5% (n=14), 5% (n= 4) and 3.8% (n=3) were between 33-36, 28-32, < 28, and > 40 weeks, respectively. The mode of delivery was emergency caesarean section (C/S), vaginal delivery and elective C/S in 38.8%, 35% and 26.2%, respectively. The birth weight was between 2.6–4.0 Kilogram (Kg) in 47.5% (n=38) and 1.6-2.5Kg, 1.0-1.5Kg and <1Kg in 35% (n=28), 11.3% (n=9) and 6.3% (n=5) of the newborns, respectively. Prematurity (25%) and birth asphyxia (19%) were the most common causes of NICU admission (Figure 1).

While 31.2% (n=25) of the mothers did not have a risk factor that predisposed their newborns to sepsis, 68.8% (n=55) had. Among women with risk factors, UTI was the most frequent (60%), followed by liquorrhoea (52.7%), intrapartum fever (5.5%) and both vaginal discharge and others (Dysentery and Malaria) shared the least percent (3.6%). Of those with risk factors; 67.3% (n=37) received treatment, while 29.1% (n=16) didn't. Regarding liquorrhoea, 29 women (36.3%) reported its presence while 49 women (61.3%) didn't. Of those with liquorrhoea, it lasted for more than 16 hours in 22 (75.9%) of mothers and for less than 16 hours in 7 (24.1%) mothers. Only 37.9% (n=11) of mothers with liquorrhoea received antibiotics, whereas 62.1% (n=18) didn't. While 65% (n=52) of mothers received intrapartum antibiotic (all those who delivered by caesarian section), all mothers who delivered by vaginal delivery (35%, n=28) did not receive intrapartum antibiotic.

Results of Umbilical swab culture

About 79.7% (n=63) of the patients had no growth in their umbilical swab culture, while 20% (n=16) had positive swab culture. Of the positive swab results, *Staphylococcus aureus* was the commonest organism isolated (37.5%), followed by *Pseudomonas spp.* (18.75%), *Klebsiella spp*. (12.5%) and others that formed 31.25% (n=5) (Figures 2).

Table 1 shows the association between the gestational age and umbilical colonization where the most (62.5%) colonized neonates were 37- 40 weeks of gestation Moreover, 50% of colonized patients were born by V.D, 31.25% by emergency C/S and 18.75% were born by elective C/S (Figure 3).

Table 2 shows the association between umbilical colonization and maternal 3rd trimester risk factors for sepsis; 37.5% of the mothers with colonized babies had no risk factor, 31.25% had UTI and 31.25% had liquorrhoea, intrapartum fever and other causes shared the same percent (6.25%) while no mother with history of offensive vaginal discharge had a colonized baby. The two patients who encountered *Klebsiella spp.* had their mothers having liquorrhoea for more than 16 hours; 50% of those who had *Staphylococcus aureus* had their mothers having liquorrhoea; 33.3% > 16 hours and 16.6% < 16 hours (Table 3).

Results of Blood cultures

Regarding blood culture results, 56 patients (70%) had negative blood culture while 17 patients (21.25%) were positive; 8.75% (n=7) were missing either because the patients had died before taking the samples or the caregivers changed their minds and declined to give consent. Of the positive group; the commonest organisms isolated were *Pseudomonas spp.* (41.2%), *Klebsiella spp.* (29.4%) and *Staphylococcus aureus (*17.6%) (Figure 4).

The relation between swab culture results and blood culture results

The association between the swab culture and blood culture was performed by a chi square test with the result that 58.75% (n=47) of the patients had no growth in both swab and blood cultures, but in those patient who showed growth in both cultures; none had matched (p value=0.009). It was found that of the six patients with *Staphylococcus aureus* colonization, four had no growth in their blood culture while one patient had gram negative bacilli (of the others category) and another one had a missing result of blood culture. Regarding patients with *Pseudomonas spp*. colonization (n=3), two had no growth in their blood culture while one had *Staphylococcus aureus* grown in the blood. Of those with *Klebsiella spp.* colonization (n=2), one had no growth in blood culture while the other's blood culture result was missing. Among neonates colonized by the others category (n=5), two had no growth in blood while three (two with gram negative *Coccobacilli* and one with *Coliform spp.*) had *Pseudomonas spp*. in blood culture (Table 4).

According to this study, umbilical swab culture has a negative predictive value of 81% for early neonatal (blood culture positive) infection, 36% positive predictive value, specificity of 84% and sensitivity of 31% (Table 5).

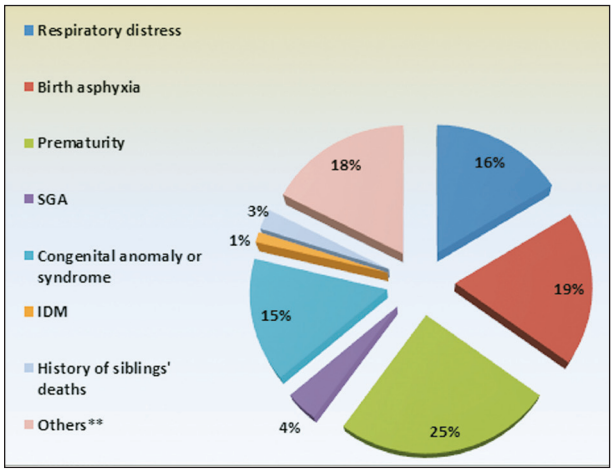


Figure 1. Causes of admission of the study group to the NICU*.

*NICU= Neonatal intensive care unit, SGA = small for gestational age, IDM = Infant of diabetic mother. ** Others: Premature rupture of membranes (PROM), maternal chorio-amnionitis, mother with primary immunodeficiency, facial lacerations due to face presentation, Jaundice, meconium stained liquor and baby of in-vitro fertilization.

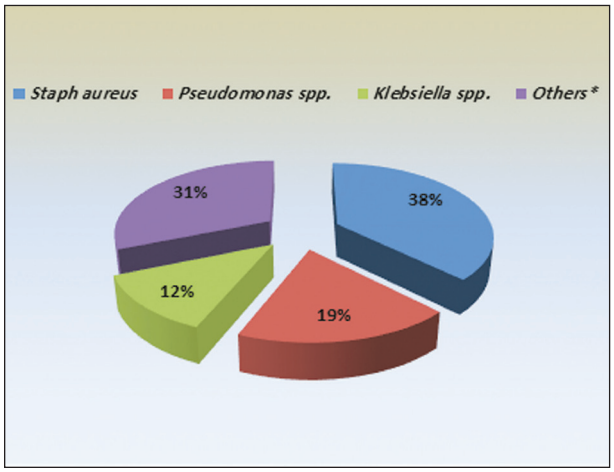


Figure 2. The distribution of positive umbilical swab culture results according to the cultured organisms

*Two had gram negative *Coccobacilli*, two had *Enterococcus faecalis* and one was colonized by *Coliform spp*.

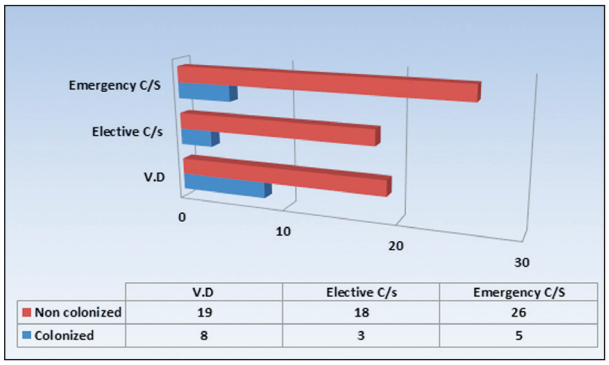
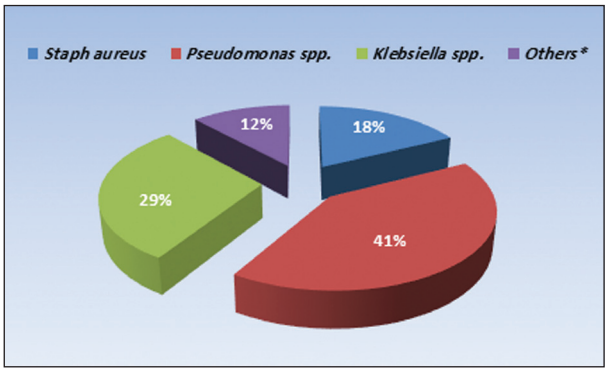


Figure 3. The association between umbilical colonization and modes of delivery in the study group.

VD = vaginal delivery. C/S = caesarian section.
* One patient born by V.D had a missing swab culture result.



* Others= *Citrobacter spp.* and gram negative bacilli

Figure 4. Distribution of positive blood cultures according to the organism.

Table 1. The association between umbilical colonization and gestational age of the study group (n=80, $\chi^2 = 3.445$, p value = 0.48).

Gestational age in weeks	Umbilical colonization		Total
	Yes	No	
< 28	0	4	4
28- 32	1	13	14
33-36	4	12	16
37-40	10	31	41
> 40	1	2	3
Missing*	0	1	1
Total	16	63	79

* One umbilical swab result was missing; the patient's gestational age was between 37-40 weeks.

Table 2. The association between umbilical colonization and risk factors encountered during third trimester of pregnancy among mothers of the study group (n=80, $\chi^2 = 2.765$, p value = 0.73).

Risk factors	Umbilical colonization		Total
	Yes	No	
None	6	17	23
UTI	5	27	32
Offensive vaginal discharge	0	2	2
Intra partum fever	1	2	3
Liquorrhoea**	5	24	15
Others	1	1	2
Missing*	0	2	2

* One swab culture result was missing, while the mother had urinary tract infection (UTI) as a risk factor.

** Liquorrhoea occurred sometimes in association with other risk factors and that made the total number more than the actual sample size.

Table 3. The association between outcome of umbilical swab culture results and duration of liquorrhoea in mothers of the study group (n=80, χ^2 =10.49, p value = 0.23).

Swab culture result	Duration of liquorrhoea			Total
	No Liquorrhoea	< 16 hours	> 16 hours	
No growth	37	6	18	61
Staphylococcus aureus	3	1	2	6
Pseudomonas spp.	3	0	0	3
Klebsiella spp.	0	0	2	2
Others	5	0	0	5
Missing*	1	0	0	1
Total	49	7	22	78

*Two Missing data (it is not known if the mother had liquorrhoea or not)

Table 4. Matching of organisms in both umbilical swab and blood cultures of the study group (n=80 ,χ^2 =32.25, p value = 0.009).

Swab culture results	Blood culture result					Total
	No growth	Staphylococcus aureus	Pseudomonas spp.	Klebsiella spp.	Others**	
No growth	47	2	3	5	1	58
Staphylococcus aureus	4	0	0	0	1	5
Pseudomonas spp.	2	1	0	0	0	3
Klebsiella spp.	1	0	0	0	0	1
Others***	2	0	3	0	0	5
Total	56	3	6	5	2	72*

*The total number is less than the actual number by 8 because 7 blood cultures and 1 swab culture were missing.

** Others (in blood culture) = *Citrobacter spp.* and gram negative bacilli.

*** Others (in swab culture) = gram negative coccobacilli (two patients), *Enterococcus faecalis* (two patients) and *Coliform spp.*

Table 5. Swab culture as a predictor for blood culture results*.

Swab culture result	Blood Culture result		Total
	+ve	-ve	
+ve	5	9	14
-ve	11	47	58
Total	16	56	72

*Sensitivity: 31%, Specificity: 84%, Positive Predictive Value: 36%, Negative Predictive Value: 81% (Seven blood cultures and one swab culture were missing).

DISCUSSION

This study was conducted to examine the relation between umbilical colonization occurring in the first 12 hours of life and blood culture results among neonates admitted to the NICUs of Soba University Hospital and Saad Abul-ella Teaching Hospital. Seven blood culture results and one umbilical swab culture result were missing. This most probably affected the accuracy of the final result and may explain the differences between this study and other similar studies "putting in mind that; in our study the sample size was small'' and missing data represented a significant percent of the total number (almost 10%).

Within these first 12 hours, 20% of the included neonates had positive umbilical swab cultures. In comparison, a study conducted in Kolkata, India in 2015 showed that 82% of the inborn neonates had growth in their umbilical swab cultures within the first six hours of life while all of them were colonized within 72 hours[7]. Another study conducted in Bangladesh by Chan et al found that "within the first day of life", 54.6% of the neonates were colonized[8]. These differences may be attributed to differences in the environment and infection control measures, but also lack of transport media in our study may be a cause of the small percent of colonized neonates. While the 2017 study didn't report a use of transport media, Chan et al mentioned the use of Amies transport medium directly after sampling[8]. Some studies, alternatively, incorporates the umbilical swab immediately into the chosen culture media without a transport media, and the rate of contamination was nearly 90%[9].

The commonest colonizer was *Staphylococcus aureus* (37.5%) followed by *Pseudomonas spp.* and then *Klebsiella spp.* Forozeshfard et al agreed with us in the predominance of *Staphylococcus aureus "*but they took the samples on day 2 of life"[2]. Also, Goswami et al found that the commonest organism was *Staphylococcus aureus* followed by coagulase negative *Staphylococcus* (CONS), then *Pseudomonas spp.* in samples taken within the first six hours as well as those taken after 72 hours[7].

Unlike what literature stated, this current study found that most of the colonized neonates (62.5%) were term ''gestational age between 37 and 40", while no growth occurred in those less than 28 weeks. Again, this may be due to the small sample size and that the majority of the included neonates were term[6].

Chan et al reported in their systematic review and meta-analysis that twenty-seven studies presented data on maternal risk factors and neonatal infections[10]. In studies where mothers experienced preterm labor, 2.9% (95% confidence interval (CI) of 1.7%-4.2 %) of the newborns had positive cultures. In studies where mothers had preterm labor, 7.0% (95% CI 1.4-12.6) of the newborns had clinical signs of infection.

Half of the colonized neonates were born by vaginal delivery and the other half by caesarean section (31.25% by emergency C/S and 18.75% by elective C/S). This may be related to the quality of settings preceding each of these procedures. But also in this study, all the mothers who delivered by caesarean section received intrapartum antibiotics while none of those delivered by vaginal delivery received antibiotics. This may give a clue that neither mode of delivery nor intrapartum antibiotics has influence on umbilical colonization.

The majority of colonized babies had maternal associated factors; predominantly UTI and liquorrhoea (especially >16 hours). Chan et al stated in their systematic review that "Pregnant women with risk factors, particularly PPROM, preterm labor, and prolonged rupture of membranes, had a high prevalence of neonatal infection"[10].

Regarding blood culture results, the commonest organism was *Pseudomonas spp*. followed by *Klebsiella spp*. unlike, a study done in Soba University Hospital from March to July 2016 that showed that methicillin resistant *Staphylococcus aureus* (*MRSA*) and *Klebsiella pneumoniae* were the most common isolated organisms[11]. This might be due to an outbreak in the period of data collection or due to some changes in infection control

policies. On the other hand, Cortese et al stated that *Streptococcus agalactiae* and *Escherichia coli* are the agents most commonly involved in early onset neonatal sepsis, the difference here might be due to environmental differences[12].

Regarding matching between the two cultures, 58.75% of the patients had no growth in both swab and blood cultures. But no matching occurred in the case that either of the cultures was positive. Dias and Saleem found the opposite in their study about Surface colonization and subsequent development of infections with multi drug resistant organisms, where they found that the total number of babies contracting infection was more in the colonized group than the non-colonized one[13]. Akturk et al "in their retrospective case–control study which was conducted in paediatric and neonatal intensive care units" found that 18.1% of carbapenem-resistant *Klebsiella pneumoniae* colonized patients in neonatal intensive care units developed systemic carbapenem-resistant *Klebsiella pneumoniae* infection[14]. Kulkarni et al found that none of the GBS colonized neonates had GBS disease; this may be supporting our finding, but in this study GBS colonization rate was only 2.52% and 1.26% in pregnant women and their neonates, respectively[15].

Finally, the umbilical swab culture has a negative predictive value of 81% for early neonatal (blood culture positive) infection, 36% positive predictive value, specificity of 84% and sensitivity of 31%. Harder et al stated in their systematic review and meta-analysis that: in outbreak settings, pooled sensitivity of body surface screening to predict sepsis was 98% (95 CI of 60% to 100%), while pooled specificity was 26% (95% CI of 0.5% to 96%) and that evidence quality was low for all outcomes[16]. As stated above, small sample size, missing culture results and lack of transport media might all be contributing to this significant difference.

These current study limitations include the small sample size, the lack of investigations which are needed to define the source of the colonizers such as high vaginal swabs and swabs from the team handling the neonate within the first hours of life. Also this study depended on the investigations without much concentration on the clinical symptoms of sepsis. Although the study did not reveal significant number of umbilical colonization, yet it proved that umbilical colonization is an important cause of early neonatal infection and it needs to be further investigated.

The authors believe that Adoption of routine blood culture for babies admitted to the NICU is essential for early detection of neonatal sepsis. Also, interventional studies using antiseptics to clean the neonates' skin are needed to see if it is useful to do it as a routine in our NICUs. Liaison with other departments; e.g. the obstetrics and gynecology, infection control and microbiology department to improve the infection control measures is needed. Further studies using layer sampling to investigate the source of neonatal infections are needed to take the appropriate preventive measures.

CONCLUSION

This was a prospective cross-sectional hospital based study, performed in two neonatal intensive care units (NICU) in Khartoum City, Sudan, to correlate early umbilical bacterial colonization in relation to blood culture in neonates. The study found that 20% (n=16) of the admitted neonates had umbilical bacterial colonization within the first 12 hours of their lives and 23.3% (n=17) had positive blood culture. The commonest colonizer was *Staphylococcus aureus*, while the commonest one seen in blood culture was *Pseudomonas spp*. The majority of the colonized neonates were term. The commonest mode of delivery among colonized neonates was vaginal delivery. The conclusion was that umbilical surface colonization has a negative predictive value of 81% in detecting culture positive early neonatal infections. Therefore, it is not a reliable indicator of bacteraemia (septicaemia) in early neonatal infection. UTI and liquorrhoea were the main associated maternal factors contributing to colonization. Also, the longer the duration of liquorrhoea, the more the risk for bacterial colonization.

REFERENCES

1. Stewart D, Benitz W. Umbilical cord care in the newborn infant. *Paediatrics* 2016; 138(3):e20162149.DOI: https://doi.org/10.1542/peds.2016-2149. [Accessed 25.6.2019].

2. Forozeshfard M, Ghorbani R, Razavi M, Danaei N, Nooripour Sh. Comparison of the umbilical cord bacterial colonization in newborn infants rooming in with mothers and neonates admitted to neonatal intensive care unit. *Int J Paediatr* 2017; 5(11): 6009-6015. Available from: http://ijp.mums.ac.ir/article_9278.html. [Accessed 25.6.2019].

3. Imdad A, Bautista RMM, Senen KAA, Uy MEV, Mantaring IIIJB, Bhutta ZA. Umbilical cord antiseptics for preventing sepsis and death among newborns. Cochrane Database of Systematic Reviews 2013, Issue 5. Art. No.: CD008635. DOI:https://doi.org/10.1002/14651858.CD008635.pub2. [Accessed 2.7.2019].

4. Mullany LC, Darmstadt GL, Katz J, Khatry SK, LeClerq SC, Adhikari RK, et al. Risk of mortality subsequent to umbilical cord infection among newborns of southern Nepal: cord infection and mortality. *Paediatr Infect Dis J* 2009; 28(1):17-20.DOI: 10.1097/INF.0b013e318181fb4c. [Accessed 15.12.2019].

5. Kerur BM, Bhat BV, Harish BN, Habeebullah S, Kumar CU. Maternal genital bacteria and surface colonization in early neonatal sepsis. *Indian J Paediatr* 2006; 73(1):29-32. DOI: https://doi.org/10.1007/BF02758256. [Accessed 15.12.2019].

6. Kliegman R, St. Geme J, Blum NJ, Shah SS, Tasker RC, Wilson KM et al. Nelson Textbook of Paediatrics. 21st ed.Philadelphia: Elsevier; 2019.

7. Goswami A, Samanta M, Bhowmik A, Ray S, Raychaudhuri D, Pal NK, et al. Bacterial colonization and antibiotic sensitivity pattern of in-born and out-born neonates in a tertiary care hospital of Kolkata, India. *Int J Biol Med Res* 2019; 10(1):6616-22. [Accessed 28.12.2019].

8. Chan GJ, Modak JK, Mahmud AA, Baqui AH, Black RE, Saha SK. Maternal and neonatal colonization in Bangladesh: prevalences, etiologies and risk factors. *J Perinatol* 2013; 33(12):971.DOI: https://doi.org/10.1038/jp.2013.99. [Accessed 6.8.2019].

9. Heshmati F, Yazdanparast SA, Moosavi SA, Hussein Dargahi H, Tabibzadeh F. Aspects of bacterial colonization in newborn babies. *African Journal of Microbiology Research* 2011; 5(16) 2234-2240. [Accessed 17.3.2021]. Available at: https://academicjournals.org/ journal/AJMR/article-full-text-pdf/A948E0212065

10. Chan GJ, Lee AC, Baqui AH, Tan J, Black RE. Prevalence of early-onset neonatal infection among newborns of mothers with bacterial infection or colonization: a systematic review and meta-analysis. *BMC Infect Dis* 2015; 15(1):118.DOI: https://doi.org/10.1186/s12879-015-0813-3. [Accessed 16.11.2019].

11. Babiker W, Ahmed A, Babiker T, Ibrahim EM, Almugadam BS. Prevalence and causes of neonatal sepsis in Soba University Hospital, Sudan. *Med Microbiol Rep* 1: 2. of. 2018; 3:11-3.[Accessed 30.12.2019].

12. Cortese F, Scicchitano P, Gesualdo M, Filaninno A, De Giorgi E, Schettini F, et al. Early and late infections in newborns: where do we stand? A review. *Paediatr Neonatol* 2016; 57(4):265-73. DOI: https://doi.org/10.1016/j.pedneo.2015.09.007. [Accessed 6.1.2019].

13. Dias M, Saleem J. Surface colonization and subsequent development of infections with multi drug resistant organisms in a neonatal intensive care unit. *Ann Clin Microbiol*

Antimicrob 2019; 18(1):12.DOI: https://doi.org/10.1186/s12941-019-0312-2.[Accessed 22.12.2019].

14. Akturk H, Sutcu M, Somer A, Aydın D, Cihan R, Ozdemir A, et al. Carbapenem-resistant *Klebsiella pneumoniae* colonization in paediatric and neonatal intensive care units: risk factors for progression to infection. *Braz J Infect Dis* 2016; 20(2):134-40. DOI: https://doi.org/10.1016/j.bjid.2015.12.004. [Accessed 6.1.2019].

15. Kulkarni AA, Pawar SG, Dharmadhikari CA, Kulkarni RD. Colonization of pregnant women and their newborn infants with group-B streptococci. *Indian J Med Microbiol* 2001; 19(2):1. Available from: http://www.ijmm.org/text.asp?2001/19/2/1/6929. [Accessed 5.1.2020].

16. Harder T, Haller S, Eckmanns T, Seidel J. Sepsis prediction during outbreaks at neonatal intensive care units through body surface screening for Gram-negative bacteria: systematic review and meta-analysis. *BMC Res Notes. 2018*; 11(1):917.DOI: https://doi.org/10.1186/s13104-018-4033-y. [Accessed 22.12.2019].