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Research Article

Bacteriological Profile and Antibiotic Susceptibility of Neonatal Sepsis in Neonatal Intensive Care Unit of a Tertiary Hospital in Khartoum, Sudan 2021

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Abstract

Neonatal sepsis refers to systemic and generalized bacterial infection of newborns, documented by a positive blood culture in the first 4 weeks of life with high mortality rates in developing countries. It is a major cause of mortality and morbidity in middle and low-income countries, and it is a life-threatening emergency where antibiotics treatment is essential for favorable outcomes. This study aimed to determine the bacteriological profiles, and antibiotics susceptibility patterns of isolates of neonatal septicemia in intensive care units in a central maternal teaching hospital in Khartoum, Sudan. This was a retrospective cross-sectional study conducted in the NICU of Ribat University Teaching Hospital. A total of 94 blood cultures were positive during the study period. The organisms isolated were Pseudomonas aeruginosa (n=81, 86.2%), Klebsiella spp. (n=10, 10.6%), Enterobacter spp. (n=1, 1.1%), Enterococcus faecalis (n=1, 1.1%), and Yeast (n=1, 1.1%). Gram-negative organisms were responsible for the overwhelming majority of cases. Pseudomonas aeruginosa was the most common pathogen identified. The standard WHO first-line empirical regimen of ampicillin and gentamicin is ineffective against the organisms causing neonatal sepsis in this unit, given the 100% resistance to ampicillin and over 60% resistance to gentamicin observed across both major pathogens.

Keywords

Neonatal sepsis, Pseudomonas aeruginosa, Antibiotic susceptibility, NICU, Khartoum Sudan.

Introduction

Neonatal sepsis refers to systemic and generalized bacterial infection of newborns, documented by a positive blood culture in the first 4 weeks of life with high mortality rates in developing countries. Neonatal sepsis is a major cause of mortality and morbidity in middle and low-income countries, and it is a life-threatening emergency where antibiotics treatment is essential for favorable outcomes.[1]The prevalence of neonatal sepsis is 2824 cases per 100,000 live births, with a mortality rate of an estimated 17.6%.[2]Signs and symptoms of neonatal sepsis can range from vague non-specific symptoms to hemodynamic collapse; early symptoms include irritability, lethargy, poor feeding, respiratory distress, fever, hypothermia, or hypotension with poor perfusion and shock.[1]

Neonatal sepsis is classified into early (EOS) and late-onset (LOS) based on age at the presentation after birth. Different experts use 72 hours or 7 days as the cutoff time.[1]The timing of the transition from EOS to LOS is not clear-cut and mainly depends on the causative pathogen. Infections with group B Streptococci presenting within the first 7 days of life are usually regarded as early-onset because there are most likely of maternal origin. Whereas infections with coagulase-negative Staphylococci presenting at any age are likely to be hospital-acquired.[3]The gold standard for diagnosis of neonatal septicemia is the isolation of bacterial agents from blood culture.[4]However, the causative organisms of neonatal sepsis vary and depend on prenatal factors, health care personnel quality and quantity, delivery rooms flora, and bacterial sensitivity to antibiotics. Maternal factors like premature birth (>37 weeks), premature and prolonged (<18 hours) membrane rupture and maternal per-partum infection are strongly associated with neonatal sepsis. Besides neonatal factors like Prematurity, low birth weight, fetal distress, and metabolic disorders.[5]

Gram-negative bacteria (E. coli, P. aeruginosa, K. pneumonae, H. influenza), Staphylococcus spp, and β hemoliticus Streptococcus remain the major cause of infection with increasing resistance to commonly used antibiotics in developing countries, and there is a pressing need to conduct regular antimicrobial sensitivity patterns to better guide empirical antibiotic use and update existing guidelines.[6]Management of Neonatal Sepsis is challenging due to several reasons, the delay in making the diagnosis and initiating treatment, poor knowledge of healthcare workers, poorly equipped laboratory materials and personnel, no protocol for the management of sepsis, limited supply of antibiotics, and the knowledge of anti-microbial susceptibility patterns of common causative pathogens.[7]WHO recommendation of Ampicillin and Gentamicin combination for the treatment of neonatal sepsis may no longer be effective in treating many neonates with sepsis. This is due to the fact that 71% of Klebsiella and 50% of E. coli are reportedly resistant to Gentamicin, leading to increase mortality due to neonatal sepsis in low-income and developing countries.[8,9,10,11]

Materials and methods

Study design setting and population

This was a retrospective cross-sectional study conducted in the NICU of Ribat University Teaching Hospital. Ribat university Teaching Hospital is a tertiary level teaching hospital of Ribat university in Khartoum, Sudan. It has an eight-bed NICU, caring on average for +300 critically ill neonates annually. Neonates admitted to the NICU between January 1, 2021, and December 31, 2021, with clinical features of sepsis and who had a positive blood culture were included in the study.

Procedures

Ribat University teaching Hospital follows standard microbiological techniques. Before drawing blood, the skin is disinfected with 10% Povidone-iodine solution for 2 min, followed by 0.5% Chlorhexidine solution for 1 minute. One to three milliliters of blood is taken aseptically from a peripheral vein and injected into the BACTEC PedsPlus™(Becton Dickinson, Ireland) culture vials. It is then incubated in an automated BACTEC system at 35 ± 2 °C for 5 days as per manufacturer's instructions. Subculture and organism identification is performed as described by Koneman et al. Antibiotic susceptibility test is done using the Kirby-Bauer disc diffusion method, as per the Clinical and Laboratory Standards Institute (CLSI) guidelines (2014).

Clinical Management

After collection of blood for culture, neonates are started on empiric intravenous Ampicillin and Amikacin (first line therapy). If there is no clinical response after 48–72 h, antibiotics are upgraded to intravenous Chloramphenicol and Ofloxacin (second line) or Meropenem and Colistin (third line). These are later modified, based on culture and antibiotic susceptibility results. Blood cultures were sent for neonates with either a clinical suspicion of sepsis or risk factors for it. Sepsis was suspected in the presence of temperature instability, lethargy, feeding intolerance, respiratory distress, hemodynamic instability, convulsion, hypotonia, irritability, or bleeding diathesis. Prematurity (< 37 weeks of gestation), low birth weight (< 2500 g), history of resuscitation at birth, rupture of membrane for more than 18 h (PROM), antepartum fever, foul-smelling liquor and repeated (≥3) unclean per vaginal examinations were considered as risk factors for neonatal sepsis.

Statistical analysis

Analysis was done using the Statistical Package for Social Sciences (SPSS) version 21. Summary of measures were reported as percentage for categorical variables and as mean with standard deviation for quantitative variables. Fisher's exact test was used to infer any differences between the categorical variables and p-value of less than 0.05 was considered statistically significant.

Ethical consideration

Ethical approval for this study was obtained from the Research Ethics Committee of Ribat University Teaching Hospital. Because this was a retrospective study based on existing laboratory and clinical records, individual informed consent from patients or guardians was not required. All patient data were handled confidentially and anonymized prior to analysis. No patient identifiers were included in the dataset. The study was conducted in accordance with the Declaration of Helsinki principles for research involving human subjects.

Results

A total of 94 blood cultures were positive during the study period. The organisms isolated were Pseudomonas aeruginosa (n=81, 86.2%), Klebsiella spp. (n=10, 10.6%), Enterobacter spp. (n=1, 1.1%), Enterococcus faecalis (n=1, 1.1%), and Yeast (n=1, 1.1%). Gram-negative organisms were responsible for the overwhelming majority of cases, accounting for 98 of every 100 positive cultures. Pseudomonas aeruginosa was the most common pathogen identified.

Antibiotic susceptibility of Pseudomonas aeruginosa

Among Pseudomonas aeruginosa isolates, ciprofloxacin showed the lowest resistance rate at 1.5% (1/66 tested), making it the most reliably active agent. Levofloxacin was similarly effective, with only 6.1% resistance (3/49). Meropenem and amikacin also showed strong activity, with resistance rates of 5.8% (3/52) and 11.1% (8/72) respectively. Piperacillin remained active in the majority of isolates, with a resistance rate of 13.3% (6/45). In contrast, Pseudomonas aeruginosa showed near-total resistance to the penicillin-class agents: ampicillin and amoxicillin were both 100% resistant. Cefalexin and cefuroxime also showed very high resistance rates of 100% and 96% respectively. Augmentin (co-amoxiclav) had a resistance rate of 96.8%. Among the third and fourth generation cephalosporins, ceftazidime showed 53.2% resistance, ceftriaxone 46.3%, and cefepime 66%. Gentamicin demonstrated 66.1% resistance. Colistin showed 73.7% resistance in Pseudomonas.

Antibiotic susceptibility of Klebsiella spp.

Klebsiella spp. (n=10) showed a particularly severe resistance profile. All isolates were resistant to ampicillin (100%), amoxicillin (100%), cefalexin (100%), ceftriaxone (100%), cefuroxime (100%), and cefexime (100%). Cefepime showed 88.9% resistance and ceftazidime 100%. Gentamicin resistance stood at 62.5% and meropenem at 50%. Colistin was the most reliably active agent for Klebsiella, with only 11.1% resistance (1/9 isolates), and amikacin showed 12.5% resistance.

Antibiotic	**P. aeruginosa (n=81) No. resistant/tested (%)**	**Klebsiella spp. (n=10) No. resistant/tested (%)**
Co-trimoxazole	2/31 (6.5)	2/2 (100)
Ampicillin	15/15 (100)	1/1 (100)
Amoxicillin	30/30 (100)	9/9 (100)
Piperacillin	6/45 (13.3)	N/T
Augmentin	30/31 (96.8)	3/7 (42.9)
Ceftriaxone	19/41 (46.3)	9/9 (100)
Cefotaxime	22/36 (61.1)	7/7 (100)
Cefalexin	28/28 (100)	6/6 (100)
Cefepime	35/53 (66)	8/9 (88.9)
Cefuroxime	24/25 (96)	5/5 (100)
Ceftazidime	33/62 (53.2)	8/8 (100)
Gentamicin	39/59 (66.1)	5/8 (62.5)
Amikacin	8/72 (11.1)	1/8 (12.5)
Ciprofloxacin	1/66 (1.5)	3/8 (37.5)
Levofloxacin	3/49 (6.1)	3/9 (33.3)
Meropenem	3/52 (5.8)	5/10 (50)
Imipenem	11/28 (39.3)	1/1 (100)
Colistin	28/38 (73.7)	1/9 (11.1)

Table 1. Antibiotic resistance rates among isolates from neonatal sepsis, Ribat University Teaching Hospital NICU, 2021

Discussions

This study found that gram-negative organisms were responsible for almost all positive blood cultures in the NICU, with Pseudomonas aeruginosa being the dominant pathogen at 86.2% of isolates. This is consistent with other studies from Sudan and the wider African region which have similarly documented a shift toward gram-negative organisms as the leading cause of neonatal sepsis, particularly in hospital settings with prolonged admissions and invasive procedures.[6]

Perhaps the most clinically significant finding of this study is the near-complete resistance of the isolated organisms to the WHO-recommended first-line regimen of ampicillin and gentamicin. Ampicillin showed 100% resistance in both Pseudomonas aeruginosa and Klebsiella spp., and gentamicin showed 66.1% resistance in Pseudomonas and 62.5% in Klebsiella. This reinforces the concern raised by multiple authors that the standard WHO empiric regimen is increasingly ineffective in low and middle-income settings.[8,9,10,11]

Among antibiotics that remain reliably active, ciprofloxacin stood out with only 1.5% resistance in Pseudomonas aeruginosa, followed by levofloxacin at 6.1%, and meropenem at 5.8%. Amikacin and piperacillin also showed comparatively low resistance rates of 11.1% and 13.3% respectively in Pseudomonas.[9]These findings suggest that fluoroquinolones and carbapenems, used alongside amikacin, currently represent the most reliable treatment options for Pseudomonas sepsis in this unit. However, it is worth noting that the use of fluoroquinolones in neonates remains controversial due to concerns about cartilage toxicity, and their use should be guided by sensitivity results and clinical judgment on a case-by-case basis.[10]

For Klebsiella spp., the picture is more alarming. Resistance to almost all cephalosporins was complete (100%), and meropenem resistance was already at 50%, suggesting the possible emergence of carbapenem-resistant Klebsiella in this NICU.[10,11]The only agents with retained activity were colistin (11.1% resistance) and amikacin (12.5% resistance). The high colistin resistance seen in Pseudomonas (73.7%) is a particularly troubling finding since colistin is regarded as a last-resort antibiotic.[8]

The limitation of this study is that it was restricted to one year of data from a single NICU, and the relatively small sample size for organisms other than Pseudomonas means that the resistance figures for Klebsiella, Enterobacter, and E. faecalis should be interpreted with caution.

Conclusions

Neonatal sepsis in the NICU of Ribat University Teaching Hospital is predominantly caused by gram-negative organisms, with Pseudomonas aeruginosa accounting for the vast majority of isolates. The standard WHO first-line empirical regimen of ampicillin and gentamicin is ineffective against the organisms causing neonatal

sepsis in this unit, given the 100% resistance to ampicillin and over 60% resistance to gentamicin observed across both major pathogens. Ciprofloxacin, levofloxacin, meropenem, amikacin, and piperacillin currently represent the most active agents for Pseudomonas aeruginosa, while colistin and amikacin remain the most reliable options for Klebsiella spp. These findings highlight the clear need to revise empiric antibiotic treatment guidelines for neonatal sepsis in this hospital based on local susceptibility data.

References

1. M, Gray CP (2022) Neonatal Sepsis. In: StatPearls [Internet]. Treasure Island (FL): StatPearls Publishing.

2. Fleischmann, C., Reichert, F., Cassini, A., Horner, R., Harder, T., Markwart, R., Tröndle, M., Savova, Y., Kissoon, N., Schlattmann, P., Reinhart, K., Allegranzi, B., & Eckmanns, T. (2021). Global incidence and mortality of NEONATAL SEPSIS: A systematic review and meta-analysis. Archives of Disease in Childhood, 106(8), 745–752. https://doi.org/10.1136/archdischild-2020-320217

3. Tesini, B. L. (2022, July 1). Neonatal sepsis - pediatrics. MSD Manual Professional Edition. Retrieved July 4, 2022, from https://www.msdmanuals.com/professional/pediatrics/infections-in-neonates/neonatal-sepsis

4. Iroh Tam, P.-Y., & Bendel, C. M. (2017). Diagnostics for neonatal sepsis: Current approaches and future directions. Pediatric Research, 82(4), 574–583. https://doi.org/10.1038/pr.2017.134

5. Cortese, F., Scicchitano, P., Gesualdo, M., Filaninno, A., De Giorgi, E., Schettini, F., Laforgia, N., & Ciccone, M. M. (2016). Early and late infections in newborns: Where do we stand? A Review. Pediatrics & Neonatology, 57(4), 265–273. https://doi.org/10.1016/j.pedneo.2015.09.007

6. Gasim Khalil, E. A. (2019). Late onset neonatal sepsis in Sudan: Incidence, bacteriological profiles, patterns of antimicrobial resistance and fatality. Academic Journal of Pediatrics & Neonatology. https://doi.org/10.19080/ajpn.2019.08.555784

7. Ni, P., & Le, Y.-I. (2017, June 16). Challenges in the management of sepsis in a resource-poor setting. International Journal of Clinical Medicine. Retrieved July 4, 2022, from https://www.scirp.org/journal/paperinformation.aspx?paperid=7718z

8. Thaver, D., Ali, S. A., & Zaidi, A. K. (2009). Antimicrobial resistance among neonatal pathogens in developing countries. Pediatric Infectious Disease Journal, 28(1). https://doi.org/10.1097/inf.0b013e3181958780

9. Moniri R, Mosayebi Z, Movahedian M, Mousavi GA (2006) Increasing Trend of Antimicrobial Drug Resistance in Pseudomonas aeruginosa causing septicemia. Ira J Pub Heal 35(1): 58-62.

10. Chaurasia S, Sivanandan S, Agarwal R, Ellis S, Sharland M, et al. (2019) Neonatal sepsis in South Asia: huge burden and spiralling antimicrobial resistance. BMJ 364: k5314.

11. Bandyopadhyay T, Kumar A, Saili A, Randhawa VS (2018) Distribution, antimicrobial resistance and predictors of mortality in neonatal sepsis. J Neonatal Perinatal Med 11(2): 145-153.