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Original article

Drug Utilization Study in the Neonatal Intensive Care Unit at Zawia Medical Center, Zawia, Libya

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Abstract
Drug utilization research was critical in assessing medication prescribing, use, and management. This was particularly important in neonatal intensive care units, where evidence from clinical trials was limited, and treatment decisions relied heavily on real-world practice. This study aimed to analyze drug utilization patterns and evaluate prescribing practices using the WHO core indicators. A cross-sectional, observational, and retrospective study was conducted in the Neonatal Intensive Care Unit, Zawia, Libya, from September to December 2023. Data from neonates who received at least one medication were collected, including demographic characteristics, clinical outcomes, and prescribed drugs. Medications were categorized using the World Health Organization Anatomical Therapeutic Chemical classification, and prescribing practices were evaluated using World Health Organization core indicators. Of the 372 neonates admitted, 167 met the inclusion criteria. The mean length of stay was 7.52 days, with a discharge rate of 55.7% and a mortality rate of 17.4%. Neonatal sepsis (71.2%) and respiratory distress syndrome (50.3%) were the most prevalent conditions. A total of 853 medications were prescribed, with anti-infective agents accounting for 68.2%. Gentamicin (98.2%) and ampicillin (96.4%) were the most frequently used medications. The average number of drugs per neonate was 5.1, and 96.8% of prescribed drugs were listed in the Libyan Essential Medicines List. The findings emphasized the importance of effective antibiotic stewardship and strengthened infection control to prevent neonatal complications. Strategies such as the active participation of clinical pharmacists and the implementation of therapeutic drug monitoring were recommended to optimize medication use, enhance medication safety, and improve treatment outcomes in neonatal intensive care units.
Keywords. Drug Utilization, Neonatal Intensive Care Unit, WHO Core Indicators, Antibiotic Use.

Introduction

Drug utilization research is a fundamental tool for assessing prescribing patterns and promoting rational medicine use within healthcare systems. It systematically analyzes how drugs are prescribed, dispensed, and used. This generates essential evidence to identify inappropriate practices, optimize therapeutic outcomes, and guide policy development. Such evaluations are particularly important in settings where real-world data are needed to complement limited clinical evidence [1, 2].

Neonates admitted to neonatal intensive care units (NICUs) constitute one of the most vulnerable patient populations. Their immature organ systems and rapidly changing physiology led to significant variability in pharmacokinetics and pharmacodynamics, making drug response unpredictable. Consequently, dosing regimens established for adults or older children cannot be directly applied. The lack of clinical trials in this age group emphasizes the importance of evaluating real-world drug use to ensure safe and effective therapy [3, 4]. This study was conducted to assess prescribing patterns and evaluate drug utilization in the NICU at Zawia Medical Center, Zawia, Libya. It uses the WHO Anatomical Therapeutic Chemical (ATC) classification and core prescribing indicators to analyze the types, frequency, and indications of prescribed medications. National data in this domain are limited, and this research provides essential evidence to support rational prescribing and inform policy decisions in neonatal pharmacotherapy within the Libyan context.

Methods

This cross-sectional, observational, and retrospective study was conducted in the NICU at Zawia Medical Center, Zawia, Libya, from September to December 2023. The NICU, equipped with 30 beds and essential medical equipment, admits only inborn neonates and provides continuous critical care through a multidisciplinary team. Neonates included in the study were those admitted to the NICU and prescribed at least one medication. Neonates receiving only fluids, parenteral nutrition, supplements (except ferrous sulfate and phytonadione), blood products, oxygen, phototherapy, or vaccinations were excluded, along with non-therapeutic agents such as IV solutions and certain electrolytes, in accordance with prior studies [5]. Data were extracted from medical records, including demographic details, mode of delivery, reasons for admission, clinical outcomes (mortality and length of stay), laboratory findings, and medication prescriptions to assess utilization patterns. Medications were classified using the WHO Anatomical Therapeutic Chemical (ATC) system, and WHO core prescribing indicators were applied to evaluate prescribing practices, including the average number of drugs per neonate, the percentages of antibiotics and injections prescribed, and the proportion of drugs from the Libyan National Essential Medicines List. Data

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were analyzed using SPSS version 27 with descriptive statistics, and the study received ethical approval from the Scientific Research Ethics Committee at the University of Tripoli (SREC/010/73).

Results

Demographic and clinical characteristics

Of the 372 neonates admitted to the NICU during the study period, 167 met the inclusion criteria, while 205 were excluded because they did not receive any medications. As shown in Table 1, males represented 59.3%, and most neonates were full-term with normal birth weight. Cesarean section (C/S) was the predominant mode of delivery. The mean length of hospital stay was 7.5 days (range 1–38). At discharge, 55.7% of neonates were released in good condition, 17.4% died, 24.5% were discharged against medical advice (DAMA), and 2.4% were transferred to other facilities. Preterm neonates accounted for a notable proportion of admissions, with a small percentage born very preterm. Low and very low birth weight categories were also represented among the admitted neonates.

Table 1: Demographic and clinical characteristics of neonates in the NICU at Zawia Medical Center

Total number of neonates	**167**	
	N	**%**
Sex		
Male	99	59.3%
Female	68	40.7%
Gestational age		
Term (≥ 37 weeks)	96	57.5%
Moderate to late preterm (32_36 weeks)	57	34.1%
Very preterm (28-31 weeks)	9	5.4%
Extremely preterm (< 28 weeks)	5	3%
Birth weight		
NBW > 2500 g	117	70%
LBW < 2499 g	39	23.4%
VLBW< 1500 g	8	4.8%
Extremely LBW < 1000 g	3	1.8%
Mode of delivery		
NVD	59	35.3%
C/S	108	64.7%
Clinical outcome		
Discharge	93	55.7%
Death	29	17.4%
DAMA	41	24.5%
Transfer	4	2.4%
Mean length of stay	7.52	Min 1, Max 38

Morbidities

Figure 1 presents the morbidities among the study neonates. Neonatal sepsis was the most common morbidity (71.2%), followed by respiratory distress syndrome (RDs) (50.3%), neonatal jaundice (43.7%), and prematurity (42.5%). Other notable conditions included low birth weight (29.9%), necrotizing enterocolitis (NEC) (18.6%), meconium-stained liquor (MSL) (15%), cord around the neck (10.8%), hypoxic-ischemic encephalopathy (7.8%), neonatal convulsions (7.8%), and infant of a diabetic mother (IDM) (6.6%).

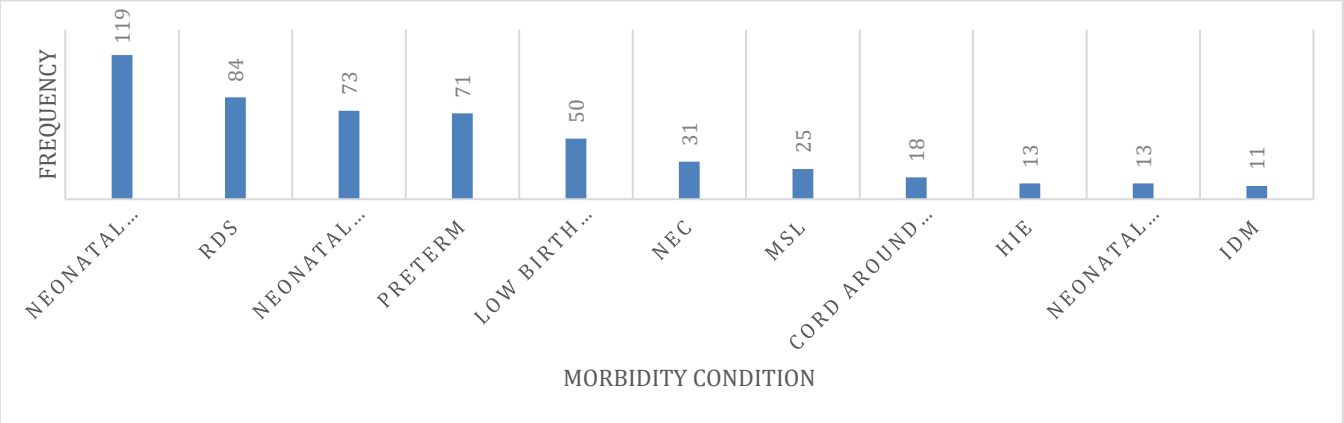

Figure 1. Morbidities observed in the neonatal intensive care unit at Zawia Medical Center

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Medications prescribed to neonates

Drugs classified according to the WHO-ATC system are presented in Table 2. A total of 853 medicines were prescribed. Anti-infective agents were the largest group (68.2%), followed by drugs for the respiratory system (12.3%) and other categories such as supplements (11.2%). Cardiovascular drugs represented 3.3%, nervous system drugs 3.2%, and alimentary tract drugs 1.8%.

Table 2: Drugs used according to the WHO-ATC classification system in the neonatal intensive care unit at Zawia Medical Center

Total medicines	**WHO-ATC category**					
853	Anti-infective	Respiratory system	Cardiovascular system	Nervous system	Alimentary tract	Others
N	582	105	28	27	15	96
%	68.2%	12.3%	3.3%	3.2%	1.8%	11.2%

As shown in Table 3, among anti-infective agents, gentamicin (98.2%) and ampicillin (96.4%) were most frequently used, followed by amikacin (50.9%), cefotaxime (42.5%), and metronidazole (25.1%). Respiratory agents included surfactant (28.7%) and ipratropium bromide nebulizer (17.4%), while common cardiovascular drugs were furosemide and adrenaline (6% each). In the nervous system, phenobarbitone (9.6%) and caffeine citrate (4.8%) predominated. Other frequently used agents were omeprazole (9%), hydrocortisone (9.6%), dexamethasone (5.4%), and various supplements (11.3%).

Table 3: Distribution of drugs used in the neonatal intensive care unit at Zawia Medical Center, categorized according to WHO-ATC codes

Drug Category	**ATC code**	**Name of drugs**	**Neonates (N)**	**Frequency (%)**
Anti-infective	J01GB03	Gentamicin	164	98.2%
	J01CA01	Ampicillin	161	96.4%
	J01GB06	Amikacin	85	50.9%
	J01DD01	Cefotaxime	71	42.5%
	J01XD01	Metronidazole	42	25.1%
	J01DH02	Meropenem	30	18%
	J01MA02	Ciprofloxacin	8	4.8%
	J01DD02	Ceftazidime	8	4.8%
	J01DB04	Cefazolin	6	3.6%
	J01XB01	Colistin	5	3%
	J01XA01	Vancomycin	1	0.6%
	J02AC01	Fluconazole	1	0.6%
Respiratory system	R07AA	Surfactant	48	28.7%
	R03BB01	Ipratropium bromide nebulizer	29	17.4%
	R07AA20	N/S Nebulizer	18	10.8%
	R03BB01	Aminophylline	1	0.6%
Cardiovascular system	C03CA01	Furosemide	10	6%
	C01CA04	Dopamine	8	4.8%
	C01CA24	Adrenaline	10	6%
Nervous system	N03AA02	Phenobarbitone	16	9.6%
	N06BC01	Caffeine citrate	8	4.8%
	N03B02	Phenytoin	2	1.2%
	N05CD08	Midazolam	1	0.6%
Alimentary tract	A02BC01	Omeprazole	15	9%
Endocrine system	H02AB09	Hydrocortisone	16	9.6%
	H02AB02	Dexamethasone	9	5.4%
Others	Supplement		96	57.5%

Prescribing patterns according to WHO indicators

The average number of drugs prescribed per neonate was 5.1. Antibiotics were included in 68.2% of prescriptions, and 80.9% of medications were administered by injection. Importantly, 96.8% of all prescribed medicines were from the Libyan National Essential Medicines List (Table 4).

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Table 4: Prescribing patterns in the neonatal intensive care unit at Zawia Medical Center based on WHO core indicators

WHO core indicators	Value
Total number of drugs prescribed	853
Average number of drugs per neonate	5.1
Percentage of prescriptions with antibiotics	68.2%
Percentage of prescriptions with injection	80.9%
Percentage of drugs prescribed from the Libyan Essential Drug List	96.8%

Discussion

This study, along with a previously published work conducted at Aljala Maternity and Gynecology Hospital, Tripoli, Libya [6], provides a comprehensive analysis of drug utilization patterns and morbidities in a NICU in Libya, highlighting critical clinical and pharmacological trends. The findings in this study show that male neonates made up 59.3% of NICU admissions. This male predominance has been observed in other studies, possibly because male infants often have greater vulnerability to perinatal complications [6-13]. The C/S rate was 64.7%, reflecting the higher likelihood of operative delivery in high-risk pregnancies. C/S is commonly associated with neonatal complications requiring intensive care, and studies have shown that neonates delivered by C/S have a significantly increased risk of NICU admission compared to vaginal delivery [14]. The mortality rate was 17.4%, which is substantial, and 24.5% of neonates were DAMA. High DAMA rates can compromise neonatal outcomes and are often linked with socioeconomic factors, inadequate health literacy, or dissatisfaction with care [15]. Mortality of this magnitude demonstrates the need for improved perinatal, obstetric, and neonatal care.

The elevated rate of neonatal sepsis (71.2%), where neonatal sepsis remains a leading cause of morbidity and mortality, may be attributed to several risk factors such as prematurity, invasive procedures, and limited infection control practices, common challenges in under-resourced healthcare systems [16, 17]. The high proportion of anti-infective use observed in this study aligns with global findings [18]. Several factors contribute to this pattern, with the primary contributing factor being the empirical initiation of broad-spectrum antibiotics to treat suspected infections before pathogen identification. Although this approach is often lifesaving and can reduce mortality, it also increases the risk of antibiotic overuse. Delays in obtaining culture and sensitivity results further extend empirical therapy, particularly in the absence of rapid diagnostic tools. In this study, although blood cultures were performed to identify causative pathogens, the use of anti-infectives remained high, suggesting that antibiotics were frequently continued empirically regardless of culture results. This practice likely stems from concerns about adverse outcomes in critically ill neonates but highlights the pressing need for evidence-based antibiotic stewardship and stricter adherence to culture-guided therapy.

Gentamicin and ampicillin were the main antibiotics prescribed, consistent with global findings on empirical treatment of neonatal sepsis [7, 17-19]. They were administered to nearly all neonates; however, such extensive use suggests potential overprescription. Overuse may contribute to antimicrobial resistance, toxicity, and prolonged hospitalization. Moreover, gentamicin requires cautious dosing because of its potential nephrotoxic and ototoxic effects. Although therapeutic drug monitoring (TDM) is recommended to optimize therapy, it is not performed in this NICU, thereby increasing the risk of toxicity, particularly among neonates aged 0–7 days who have immature renal function and reduced drug clearance. The risk is further elevated in cases of hypoxic-ischemic encephalopathy (HIE), where impaired clearance enhances gentamicin accumulation and toxicity potential [20, 21].

Of particular concern was the prescribing of narrow therapeutic index (NTI) drugs such as aminoglycosides (e.g., gentamicin and amikacin), vancomycin, and certain anticonvulsants (e.g., phenobarbital) without routine TDM. TDM is essential for NTI medications to ensure efficacy while preventing toxicity, especially in neonates whose pharmacokinetics vary widely. The absence of TDM services can lead to suboptimal dosing and increased risk of serious adverse outcomes. Establishing TDM as a standard practice in NICUs is critical for safe and rational use of these high-risk medications [22]. The frequent use of respiratory medications such as surfactant and nebulized bronchodilators correlates with the high incidence of respiratory distress syndrome, particularly among preterm neonates. These findings are consistent with global data showing increased respiratory complications in premature infants due to immature lungs [23].

The use of omeprazole in neonates with NEC raises safety and efficacy concerns, especially in preterm infants. Due to immature liver and kidney function, neonates have prolonged drug clearance, increasing the risk of adverse effects such as pneumonia and sepsis. Acid suppression may also predispose to NEC by disrupting gut microbiota and natural defenses, with limited evidence supporting its benefit in this population [24]. Guidelines from the American Academy of Pediatrics and NICE discourage routine omeprazole use in neonates, recommending it only for clear indications such as severe GERD. Even in these cases, it should be used cautiously, for the shortest duration, and with monitoring for adverse effects like respiratory infections, NEC, and osteopenia [25].

The average number of drugs prescribed per neonate was 5.1, indicating a high level of polypharmacy. Such

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exposure increases the risk of adverse reactions, drug interactions, and dosing errors, especially in neonates with immature renal and hepatic function, which significantly affects drug metabolism and clearance. When compared with international reports, the average of 5.1 drugs per neonate was higher than in Portugal (3 in 2015), Italy (4 in 2016), China (3 in 2020), Ghana (2.6 in 2021), Bahrain (5 in 2021) and Pakistan (2.8 in 2018), but lower than in France (6.2 in 2019), India (5.7 in 2017) and the USA (9 in 2016). Despite the high number of medications, 96.8% adherence to the Libyan Essential Medicines List reflects a positive trend toward rational use. Injections were administered in 80.9% of cases, consistent with NICU practice, where rapid and reliable drug delivery is often required. Interventions such as regular prescription auditing and clinical pharmacist participation can help reduce inappropriate prescribing and promote rational drug use [5, 18, 26-29].

Conclusion

Overall, these findings highlight the need for stronger antibiotic stewardship, improved infection control, and better prenatal care to reduce neonatal complications. Regular prescription reviews, active clinical pharmacist participation, and the introduction of therapeutic drug monitoring (TDM) services are crucial to optimize antibiotic use, enhance safety, and improving treatment outcomes in NICUs**.**

Authors' Contributions

Naema Alouzi: Study conception and design, data collection, data analysis, interpretation, and manuscript drafting. Fathia Murabet: Clinical supervision, facilitation of data collection, and contribution to clinical data interpretation. Mufida Yamane: Supervision, critical revision of the manuscript for important intellectual content, and final approval of the version to be published.

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Conflicts of Interest

None declared.

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References

1. World Health Organization. Introduction to drug utilization research. Geneva: World Health Organization; 2003.
2. Neville H, Trenaman SC. Drug utilization research: methods and applications. Can J Hosp Pharm. 2017;70(4):325.
3. Rosli R, Dali AF, Abd Aziz N, Abdullah AH, Ming LC, Manan MM. Drug utilization on neonatal wards: a systematic review of observational studies. Front Pharmacol. 2017; 8:27. doi:10.3389/fphar.2017.00027.
4. Allegaert K, van de Velde M, van den Anker J. Neonatal clinical pharmacology. Paediatr Anaesth. 2014;24(1):30–38. doi:10.1111/pan.12176.
5. Yue Y, Chen I, Choonara T, Xiong S, Ojha J, Tang Y, Wang L, Zeng J, Shi H, Wang Mu D. Cross-sectional study of drug utilisation in a Chinese neonatal unit. J Int Med Res. 2020;48(5):300060520914197. doi:10.1177/0300060520914197.
6. Alouzi NA, Hashad NS, Yamane MA. Drug utilization pattern in the NICU: A World Health Organization-Anatomical Therapeutic Chemical Classification-based cross-sectional study. Mediterr J Pharm Pharm Sci. 2025;5(3):75-82. doi:10.5281/zenodo.16970145.
7. Chauthankar SA, Marathe PA, Potey AV, Nanavati RN. Drug utilization in neonatal intensive care unit of a tertiary-care hospital in Mumbai, India. Indian Pediatr. 2017;54(11):931–934.
8. Costa HT, Costa X, Martins RR, Oliveira AG. Use of off-label and unlicensed medicines in neonatal intensive care. PLoS One. 2018;13(9):e0204427. doi: 10.1371/journal.pone.0204427.
9. Kouti L, Aletayeb M, Aletayeb S, Hardani A, Eslami K. Pattern and extent of off-label and unlicensed drug use in neonatal intensive care units in Iran. BMC Pediatr. 2019;19(1):3. doi:10.1186/s12887-018-1362-7.
10. Opare-Asamoah K, Koffuor G, Abdul-Mumin A, Sulemana B, Saeed M, Quaye L. Clinical characteristics, medication prescription pattern, and treatment outcomes at the neonatal intensive care unit of a tertiary health-care facility in Ghana. J Res Pharm Pract. 2021;10(1):30–37.
11. Lee S, Yang M, Kim J, Cho Y, Choi N, Cho E, Park J, Choi Y, Choi K. Evaluation of off-label medication use and drug safety in a pediatric intensive care unit. Saudi Pharm J. 2023;31(9):101704. doi: 10.1016/j.jsps.2023.101704.
12. Quinn C, Sivasubramaniam P, Blevins M, Hajajra A, Taleb A, Khuri-Bulos N, Faouri S, Halasa NB. Risk factors for neonatal intensive care unit admission in Amman, Jordan. East Mediterr Health J. 2016;22(3):163–174.
13. Alonso A, Avila-Alvarez A, Eiriz M, Roca C, Gómez P, López A, Trisac J, Díaz S. Use of off-label drugs in neonatal intensive care. An Pediatr (Engl Ed). 2019;91(4):237–243. doi:10.1016/j.anpede.2018.12.002.
14. Vogel JP, Betrán AP, Vindevoghel N, et al. Use of the Robson classification to assess caesarean section trends in 21 countries: a secondary analysis of two WHO multicountry surveys. Lancet Glob Health. 2015;3(5): e260–e270. doi:10.1016/S2214-109X(15)70094-X.
15. Al-Turkistani HK. Discharge against medical advice from Neonatal Intensive Care Unit: 10 years' experience at a University Hospital. J Family Community Med. 2013 May;20(2):113-5. doi: 10.4103/2230-8229.114774. PMID: 23983563; PMCID: PMC3748645.

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16. Shane AL, Sánchez PJ, Stoll BJ. Neonatal sepsis. Lancet. 2017;390(10104):1770–1780. doi:10.1016/S0140-6736(17)31002-4.
17. Fleischmann C, Reichert F, Cassini A, et al. Global incidence and mortality of neonatal sepsis: a systematic review and meta-analysis. Lancet Infect Dis. 2021;21(2):223–232. doi:10.1016/S1473-3099(20)30459-8.
18. Al-Turkait A, Szatkowski L, Choonara I, Ojha S. Review of drug utilization studies in neonatal units: a global perspective. Int J Environ Res Public Health. 2020;17(16):5669. doi:10.3390/ijerph17165669.
19. Sridharan K, Hasan H, Al Jufairi M, Al Daylami A, Pasha S, Al Ansari E. Drug utilisation in adult, paediatric and neonatal intensive care units, with an emphasis on systemic antimicrobials. Anaesthesiol Intensive Ther. 2021;53(1):18–24. doi:10.5114/ait.2020.99784.
20. Hollander E, Tuinen E, Schölvinck E, Bergman K, Bourgonje A, Gracchi V, Kneyber M, Touw D, Mian P. Evaluation of dosing guidelines for gentamicin in neonates and children. *Antibiotics (Basel)*. 2023;12(5).
21. Hurkacz M, Nowakowska J, Paluszyńska D, Królak-Olejnik B. Individualization of treatment with gentamicin in neonates based on drug concentration in the blood serum. *Dev Period Med*. 2019;23(1):21–27.
22. Pauwels S, Allegaert K. Therapeutic drug monitoring in neonates. Arch Dis Child. 2016 Apr;101(4):377-81. doi: 10.1136/archdischild-2013-305309. Epub 2016 Jan 22. PMID: 26803050.
23. Yeung TY, Zhou Q, Kanmaz Kutman HG, Pandita A, Philippopoulos E, Jasani B. Surfactant delivery via thin catheter in preterm infants: A systematic review and meta-analysis. PLoS One. 2023 Apr 26;18(4):e0284792. doi: 10.1371/journal.pone.0284792. PMID: 37099568; PMCID: PMC10132547.
24. Smith PB. Use of Reflux Medications in Premature Infants After Hospital Discharge. Pediatrics. 2016 Dec;138(6):e20162849. doi: 10.1542/peds.2016-2849. PMID: 27940724; PMCID: PMC5127077.
25. Reinhart RM, McClary JD, Zhang M, Marasch JL, Hibbs AM, Nock ML. Reducing Antacid Use in a Level IV NICU: A QI Project to Reduce Morbidity. Pediatr Qual Saf. 2020 May 12;5(3):e303. doi: 10.1097/pq9.0000000000000303. PMID: 32607459; PMCID: PMC7297399.
26. Aamir M, Khan JA, Shakeel F, Shareef R, Shah N. Drug utilization in neonatal setting of Pakistan: focus on unlicensed and off-label drug prescribing. BMC Pediatr. 2018;18(1):242. doi:10.1186/s12887-018-1219-0.
27. Chauthankar SA, Marathe PA, Potey AV, Nanavati RN. Drug Utilization in Neonatal Intensive Care Unit of a Tertiary-care Hospital in Mumbai, India. Indian Pediatr. 2017 Nov 15;54(11):931-934. doi: 10.1007/s13312-017-1184-1. Epub 2017 Aug 24. PMID: 28849769.
28. Sridharan, K., Hasan, H., Al Jufairi, M., Al Daylami, A., Pasha, S., and Al Ansari, E. (2021). "Drug utilisation in adult, paediatric and neonatal intensive care units, with an emphasis on systemic antimicrobials." Anaesthesiol Intensive Therapy 53(1): 18-24.
29. Opare-Asamoah K, Koffuor GA, Abdul-Mumin A, Sulemana BM, Saeed M, Quaye L. Clinical Characteristics, Medication Prescription Pattern, and Treatment Outcomes at the Neonatal Intensive Care Unit of a Tertiary Health-Care Facility in Ghana. J Res Pharm Pract. 2021 May 13;10(1):30-37. doi: 10.4103/jrpp.JRPP_20_118. PMID: 34295850; PMCID: PMC8259601.

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