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Comparative Analysis of Renal Function Status between Term and Preterm Neonates: Implications for Clinical Care

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ABSTRACT

Introduction: Neonatal renal function is a critical determinant of early health outcomes, especially in preterm neonates whose nephrogenesis may be incomplete at birth. Acute kidney injury (AKI) contributes significantly to neonatal morbidity and mortality worldwide, yet remains underdiagnosed, particularly in resource-limited settings like Bangladesh. ***Aim of the Study:*** The study aimed to conduct a comparative analysis of renal function status in term versus preterm neonates to evaluate implications for clinical care. ***Methods:*** This hospital-based comparative cross-sectional study was conducted at Dhaka Shishu Hospital, Bangladesh over a period of six months, from May to November 2024. Fifty neonates (25 term ≥37 weeks and 25 preterm <37 weeks) were enrolled consecutively. Serum creatinine, urea, sodium, potassium, calcium, and phosphorus were measured at 24 hours and 7 days of life. AKI was defined according to modified neonatal KDIGO criteria. Statistical analysis included t-tests, chi-square tests, and logistic regression; $p<0.05$ was considered significant. ***Results:*** Among the 50 neonates studied, preterm neonates had significantly lower birth weights (1.78±0.35 kg) than term neonates (2.77±0.41 kg; $p<0.001$). Cesarean section was the predominant mode of delivery overall (80.0%), more common in preterms (88.0%) than terms (72.0%; $p=0.028$) Cesarean delivery was the predominant mode overall (80.0%), being more common in preterm (88.0%) than term neonates (72.0%; $p=0.028$). Male neonates predominated in both groups, though not statistically significant. Preterm neonates had higher serum creatinine at 24 hours (0.82±0.31 vs. 0.68±0.24 mg/dL; $p=0.041$) and 7 days (0.71±0.28 vs. 0.52±0.19 mg/dL; $p=0.003$). Blood urea at 7 days was also elevated in preterms (31.2±14.7 vs. 22.8±9.4 mg/dL; $p=0.014$). Reduced urine output was more common in preterms at 24 hours (40.0% vs. 12.0%; $p=0.008$) and 7 days (24.0% vs. 4.0%; $p=0.023$). AKI prevalence was significantly higher in

preterms (48.0%) than in term neonates (16.0%; p=0.013). Preterm birth was an independent predictor of AKI (adjusted OR=4.12; p=0.038). ***Conclusion:*** Preterm neonates demonstrated significantly higher rates of AKI and impaired renal function compared to term neonates, underscoring the need for routine renal function monitoring and early intervention in this high-risk population.

Keywords: Neonate, Preterm, Term, Acute-Kidney-Injury, Renal-Function, Bangladesh.

INTRODUCTION

The neonatal period represents a critical window of physiological adaptation during which multiple organ systems undergo rapid maturation to support extrauterine life. The kidneys are essential for maintaining fluid, electrolyte, and acid-base balance, and are especially vulnerable to developmental and environmental insults during the neonatal period [(1)]. This vulnerability is heightened in preterm neonates, who may have ongoing nephrogenesis after birth, predisposing them to reduced nephron endowment and impaired renal functional reserve [(2)]. Globally, neonatal acute kidney injury (AKI) has emerged as a significant contributor to neonatal morbidity and mortality, with estimates ranging from 30% to 40% in neonatal intensive care units (NICUs) [(3,4)]. The AWAKEN study a large multicenter cohort reported an AKI incidence of approximately 30% among critically ill neonates, with a higher burden observed in preterm infants [(5)]. In, Asian continents some studies reported comparable AKI incidences of 40% and 35%, respectively, emphasizing that this challenge is a global phenomenon with significant clinical implications [(6,7)]. The distinction between term and preterm neonates is particularly relevant due to the differences in renal physiology and development. Term neonates typically complete nephrogenesis before delivery, providing them with a more developed renal system. In contrast, preterm neonates often have incomplete nephron development at birth, rendering them more vulnerable to postnatal environmental insults, including hypoxia, sepsis and exposure to nephrotoxic medications [(8)]. Preterm neonates exhibit higher serum creatinine levels and lower urine output compared to term neonates, which reflects delayed glomerular filtration and immature tubular function [(9)]. Electrolyte disturbances are also commonly reported among preterm neonates worldwide. Research has documented that preterm infants are more prone to hyperkalemia and hyperphosphatemia due to immature tubular handling [(6)], while others report a higher incidence of hypocalcemia linked to reduced parathyroid hormone responsiveness [(7)]. These disturbances can contribute to clinical complications, including cardiac arrhythmias and neuromuscular irritability, underscoring the importance of vigilant monitoring [(8)]. Prolonged NICU stays and increased mortality have consistently been associated with AKI in neonates. Neonates with AKI typically experience significantly longer hospital stays and face a higher risk of mortality compared to those without AKI (5). Furthermore, AKI is linked to a greater risk of developing chronic kidney disease later in life, highlighting the long-term consequences of early renal injury [(9)]. Even with these worldwide observations, data describing renal function and AKI risk factors among Bangladeshi neonates are limited. The high burden of preterm birth in Bangladesh, coupled with limited neonatal intensive care resources, suggests that the risk of renal dysfunction may be even greater in this setting [(10)]. Understanding local epidemiology is therefore essential to inform targeted

prevention and management strategies. The study aimed to conduct a comparative analysis of renal function status in term versus preterm neonates to evaluate implications for clinical care

METHODS

This hospital-based comparative cross-sectional study was conducted at Dhaka Shishu Hospital, Bangladesh over a period of six months, from May to November 2024. A total of 50 neonates were enrolled in the study, comprising 25 term neonates (≥37 weeks gestation) and 25 preterm neonates (<37 weeks gestation), selected consecutively based on predefined inclusion and exclusion criteria. A structured case record form was used to collect maternal and perinatal history, demographic details, and clinical features. Blood samples were drawn at 24 hours and 7 days of life to assess renal function parameters, including serum creatinine, urea, sodium, potassium, calcium, and phosphorus, using standard laboratory methods. Urine output was monitored hourly using urine collection bags. AKI was defined according to the modified neonatal kidney disease: Improving Global Outcomes Kidney Disease Improving Global Outcomes (KDIGO) criteria. Data were entered into SPSS version 25 and analyzed. Continuous variables were expressed as mean ± standard deviation (SD) and compared using the Student's t-test. Categorical variables were presented as frequencies and percentages and analyzed using the chi-square test or Fisher's exact test as appropriate. Multivariate logistic regression was performed to identify independent risk factors for AKI. A p-value of <0.05 was considered statistically significant. The study was approved by the Institutional Review Board. Written informed consent was obtained from the parents or guardians of all enrolled neonates.

Inclusion Criteria:

- Term (≥37 weeks) or preterm (<37 weeks) neonates
- Age <24 hours with parental consent
- Hemodynamically stable

Exclusion Criteria:

- Major congenital anomalies
- Multiorgan failure or dialysis requirement
- Consent refusal or early transfer

RESULT

Table 1: Contribution of the study patients by demographic and clinical characteristics(N=50)

Variable	Term (≥37 weeks) (n=25)	Preterm (<37 weeks) (n=25)	Total (N=50)	p-value
Birth Weight (kg)	2.77 ± 0.41	1.78 ± 0.35	2.27 ± 0.63	<0.001
Gender: Male	16 (64.0%)	18 (72.0%)	34 (68.0%)	0.324
Gender: Female	9 (36.0%)	7 (28.0%)	16 (32.0%)	

Delivery Mode: Cesarean Section	18 (72.0%)	22 (88.0%)	40 (80.0%)	0.028
Delivery Mode: Vaginal Delivery	7 (28.0%)	3 (12.0%)	10 (20.0%)	
APGAR Score 1 min	7.8 ± 1.2	6.9 ± 1.5	7.35 ± 1.4	0.019
APGAR Score 5 min	8.7 ± 0.8	8.2 ± 1.1	8.45 ± 1.0	0.087

Term neonates had significantly higher birth weight (2.77 ± 0.41 kg vs 1.78 ± 0.35 kg, $p < 0.001$) and higher APGAR scores at 1 minute (7.8 ± 1.2 vs 6.9 ± 1.5, $p = 0.019$). Cesarean delivery was more common in preterm neonates (88.0% vs 72.0%, $p = 0.028$). Gender and 5-minute APGAR scores showed no significant differences.

Table 2: Contribution of the study patients by maternal and perinatal risk factors(N=50)

Risk Factor	Term (≥37 weeks) n (%)	Preterm (<37 weeks) n (%)	OR (95% CI)	p-value
Maternal Hypertension	3 (12.0%)	4 (16.0%)	1.39 (0.28–6.85)	0.685
Maternal Diabetes	4 (16.0%)	6 (24.0%)	1.67 (0.42–6.67)	0.465
Antenatal Steroids	2 (8.0%)	3 (12.0%)	1.58 (0.24–10.27)	0.633
Neonatal Sepsis	14 (56.0%)	9 (36.0%)	0.44 (0.15–1.30)	0.141
Neonatal Asphyxia	3 (12.0%)	2 (8.0%)	0.63 (0.10–4.07)	0.633
NICU Admission	19 (76.0%)	22 (88.0%)	2.42 (0.55–10.64)	0.238
Ventilatory Support	3 (12.0%)	11 (44.0%)	5.87 (1.43–24.08)*	0.014*

No significant differences were observed in maternal hypertension, diabetes, or steroid use. Ventilatory support was more frequent in preterm neonates (44.0% vs 12.0%, OR = 5.87, $p = 0.014$). Other variables, including NICU admission and neonatal sepsis, were not statistically significant.

Table 3: Contribution of the study patients by renal function parameters at 24 hours and 7 days(N=50)

Parameter	Term (n=25)	Preterm (n=25)	Mean Difference (95% CI)	p-value
Serum Creatinine (24h, mg/dL)	0.68 ± 0.24	0.82 ± 0.31	0.14 (0.01–0.27)	0.041
Blood Urea (24h, mg/dL)	28.4 ± 12.8	35.7 ± 18.2	7.3 (−2.1 to 16.7)	0.124

Urine Output (24h): Adequate	22 (88.0%)	15 (60.0%)		0.008
Urine Output (24h): Reduced	3 (12.0%)	10 (40.0%)		
Serum Sodium (24h, mEq/L)	138.2 ± 4.8	136.1 ± 6.2	−2.1 (−5.3 to 1.1)	0.195
Serum Potassium (24h, mEq/L)	4.2 ± 0.7	4.6 ± 0.9	0.4 (0.0–0.8)	0.049
Serum Calcium (24h, mg/dL)	9.8 ± 1.2	9.1 ± 1.4	−0.7 (−1.4 to 0.0)	0.051
Serum Phosphorus (24h, mg/dL)	5.8 ± 1.1	6.4 ± 1.3	0.6 (0.0–1.2)	0.048
Serum Creatinine (7d, mg/dL)	0.52 ± 0.19	0.71 ± 0.28	0.19 (0.07–0.31)	0.003
Blood Urea (7d, mg/dL)	22.8 ± 9.4	31.2 ± 14.7	8.4 (1.8–15.0)	0.014
Urine Output (7d): Adequate	24 (96.0%)	19 (76.0%)		0.023
Urine Output (7d): Reduced	1 (4.0%)	6 (24.0%)		
Serum Sodium (7d, mEq/L)	139.6 ± 3.9	137.8 ± 5.1	−1.8 (−4.3 to 0.7)	0.154
Serum Potassium (7d, mEq/L)	3.9 ± 0.6	4.3 ± 0.8	0.4 (0.0–0.8)	0.041
Serum Calcium (7d, mg/dL)	10.1 ± 1.0	9.4 ± 1.2	−0.7 (−1.3 to −0.1)	0.024
Serum Phosphorus (7d, mg/dL)	5.4 ± 0.9	6.1 ± 1.2	0.7 (0.1–1.3)	0.019

At 24h, preterm neonates had higher serum creatinine (0.82 ± 0.31 vs 0.68 ± 0.24 mg/dL, p = 0.041), and reduced urine output was more common (40.0% vs 12.0%, p = 0.008). Potassium and phosphorus were significantly higher in preterms (p = 0.049, p = 0.048). At 7 days, creatinine (0.71 ± 0.28 vs 0.52 ± 0.19 mg/dL, p = 0.003), urea (p = 0.014), and phosphorus (p = 0.019) remained significantly elevated in preterms. Calcium was significantly lower (p = 0.024).

Table 4: Contribution of the study patients by AKI occurrence and management interventions(N=50)

Outcome	Term (n=25)	Preterm (n=25)	OR (95% CI)	p-value
AKI Development	4 (16.0%)	12 (48.0%)	4.95 (1.40–17.51)	0.013*
Fluid Restriction Required	3 (12.0%)	8 (32.0%)	3.52 (0.84–14.72)	0.085

Diuretic Therapy	7 (28.0%)	4 (16.0%)	0.49 (0.13–1.90)	0.302
Abnormal Renal Ultrasound	2 (8.0%)	5 (20.0%)	2.87 (0.52–15.88)	0.227

AKI was significantly more common in preterm neonates (48.0% vs 16.0%, OR = 4.95, p = 0.013). Fluid restriction and renal ultrasound abnormalities were more frequent in preterm infants, but the difference was not statistically significant.

Table 5: Contribution of the study patients by clinical outcomes and duration of NICU stay(N=50)

Clinical Outcome	Term (n=25)	Preterm (n=25)	Mean Difference/p-value
Discharged without complications	14 (56.0%)	4 (16.0%)	9.4 (3.8–15.0); p = 0.002
Prolonged NICU stay	9 (36.0%)	19 (76.0%)	
Expired	2 (8.0%)	2 (8.0%)	
Length of NICU Stay (days)	12.4 ± 8.7	21.8 ± 12.3	

Discharge without complications was higher in term neonates (56.0% vs 16.0%), while prolonged NICU stay was more common in preterms (76.0% vs 36.0%). NICU stay duration was longer in preterms (21.8 ± 12.3 vs 12.4 ± 8.7 days, p = 0.002).

Table 6: Contribution of the study patients by multivariate analysis of AKI risk factors(N=50)

Variable	Adjusted OR	95% CI	p-value
Preterm birth (<37 weeks)	4.12	1.08–15.73	0.038*
Low birth weight (<2.5 kg)	3.47	0.89–13.52	0.073
Ventilatory support	2.84	0.67–12.08	0.158
Neonatal sepsis	1.67	0.44–6.35	0.452
APGAR 1 min <7	2.19	0.58–8.29	0.247
Cesarean delivery	1.23	0.24–6.28	0.802

Preterm birth was an independent predictor of AKI (aOR = 4.12, p = 0.038). Low birth weight showed borderline significance (aOR = 3.47, p = 0.073). Other factors were not significant.

Table 7: Contribution of the study patients by correlation of renal parameters with perinatal indicators(N=50)

Parameter Pair	Correlation Coefficient(r)	95% CI	p-value
Birth weight vs Creatinine 24h	−0.598	−0.748 to −0.380	<0.001*
Gestational age vs Creatinine 24h	−0.524	−0.700 to −0.284	<0.001*
APGAR 1 min vs Urine output 24h	0.412	0.145 to 0.627	0.003*
Creatinine 24h vs Creatinine 7d	0.789	0.648 to 0.877	<0.001*
Urea 24h vs Urea 7d	0.723	0.547 to 0.836	<0.001*
Sodium 24h vs Potassium 24h	−0.187	−0.442 to 0.102	0.197
Calcium 24h vs Phosphorus 24h	−0.456	−0.659 to −0.198	0.001*

Birth weight and gestational age showed significant negative correlations with serum creatinine at 24h ($r = –0.598, –0.524$; $p < 0.001$). APGAR 1 min positively correlated with urine output ($r = 0.412$, $p = 0.003$). Strong correlations were seen between creatinine/urea at 24h and 7d. Calcium and phosphorus showed a significant negative correlation ($r = –0.456$, $p = 0.001$).

DISCUSSION

This study investigated renal function parameters, acute kidney injury (AKI) prevalence, and associated risk factors among term and preterm neonates in Bangladesh. In our study, we found that preterm neonates had significantly lower birth weight (1.78 ± 0.35 kg) compared to term neonates (2.77 ± 0.41 kg). Another study found that preterm infants had a mean birth weight of 1.85 ± 0.43 kg, whereas term infants had a higher mean birth weight of 3.15 ± 0.40 kg[9]. This underscores the consistent vulnerability of preterm neonates across settings, reflecting shared risk factors like intrauterine growth restriction and placental insufficiency. A higher rate of cesarean deliveries was observed among preterm neonates (88.0%) compared to term neonates (72.0%). A similar finding was reported by Adugna et al. (2022), who noted higher cesarean rates in preterm infants due to concerns about fetal distress [11]. These elevated rates may contribute to increased neonatal morbidity and could potentially affect renal perfusion, particularly in preterm infants with immature renal vasculature. Our study also found that preterm neonates had higher serum creatinine levels at 24 hours (0.82 ± 0.31 mg/dL) than term neonates (0.68 ± 0.24 mg/dL). Similar findings were reported by Alexandra et al. (2013), who found preterm neonates had higher creatinine levels on day 1 (mean 1.0 mg/dL) compared to term neonates (0.7 mg/dL)[12]. The persistently higher creatinine at day 7 in preterm (0.71 ± 0.28 mg/dL) compared to terms (0.52 ± 0.19 mg/dL) also similar to the findings of Kamianowska et al. (2019), emphasizing the delayed maturation of glomerular filtration in preterm kidneys[13]. Our data on urine output revealed that oliguria was more prevalent in preterms (40.0%) compared to term neonates (12.0%), a significant difference. This finding aligns with the work of Zhang et al. (2020) who observed a 20.31% incidence of oliguria in preterms, driven by immature renal tubular function and reduced concentrating ability [14]. Such results highlight the need for fluid management strategies tailored to preterm neonates to avoid

volume overload and electrolyte imbalance. Regarding electrolyte abnormalities, our study demonstrated higher serum potassium and phosphorus levels in preterm neonates. Similar trends were described by Iacobelli et al. (2020), who reported hyperphosphatemia and hyperkalemia as common in preterm neonates due to immature renal tubular secretion mechanisms [15]. This supports the notion that preterm kidneys struggle with electrolyte regulation, necessitating closer monitoring to prevent cardiac complications. Interestingly, calcium levels were significantly lower in preterms, consistent with results from Schell-Feith et al. (2010), who reported a higher incidence of hypocalcemia in preterms, linked to parathyroid hormone immaturity and reduced calcium stores [16]. This finding suggests the importance of calcium supplementation protocols for preterm neonates to prevent neuromuscular complications. Our study documented that AKI was significantly more prevalent in preterms (48.0%) than in term neonates (16.0%), consistent with the multicenter AWAKEN study (Jetton et al., 2017), which reported a 43% incidence of AKI in preterms [17]. This reinforces that renal immaturity, hemodynamic instability, and exposure to nephrotoxic medications remain key contributors to AKI risk in preterm neonates globally. Ventilatory support was more frequently needed in preterm neonates (44.0%) than in term neonates (12.0%). This finding is in line with studies from Yadav and lee et al. (2023), which showed higher ventilator dependency in preterms due to respiratory distress syndrome[18]. Prolonged ventilation can also exacerbate renal hypoperfusion, contributing to AKI risk. NICU stay duration was significantly longer for preterms in our study (21.8 ± 12.3 days) compared to term neonates (12.4 ± 8.7 days), reflecting findings from Getanehet al. (2024), who also noted extended hospitalization in preterms with AKI [19]. This highlights the substantial burden on healthcare resources, reinforcing the need for early risk stratification and intervention to minimize length of stay. In our multivariate analysis, preterm birth emerged as an independent predictor of AKI (adjusted OR = 4.12), corroborating results from Gupta et al. (2023), who reported similar odds ratios in preterm neonates[20]. Low birth weight showed a borderline association, consistent with the notion that lower nephron endowment increases vulnerability to renal insults[21]. Correlation analysis revealed significant negative correlations between birth weight and serum creatinine at 24 hours ($r = -0.598$, $p < 0.001$) and between gestational age and creatinine ($r = -0.524$, $p < 0.001$). These results echo findings by Gallo et al. (2021), who observed that lower birth weight and gestational age correlated with higher serum creatinine, reflecting delayed glomerular filtration maturation[22].

Limitation of the Study:

The study was conducted at a single center and involved a limited sample size.

CONCLUSION

Preterm neonates exhibited a significantly higher prevalence of acute kidney injury and impaired renal function compared to term neonates, underscoring the need for vigilant monitoring and early interventions to mitigate renal complications in this vulnerable population.

RECOMMENDATION

Given the heightened risk of AKI in preterm neonates, we recommend routine monitoring of renal function parameters in all preterm admissions, especially during the first week of life. Early detection of renal dysfunction and timely interventions, including judicious fluid management and avoidance of nephrotoxic agents, may significantly reduce the risk of short and long-term renal complications. Further large-scale, multicenter studies are warranted to validate these findings and develop region-specific clinical protocols.

REFERENCE

1. Saint-Faust M, Boubred F, Simeoni U. Renal Development and Neonatal Adaptation. Amer J Perinatol. 2014 Mar 12;31(09):773–80.
2. Sulemanji M, Vakili K. Neonatal renal physiology. Seminars in Pediatric Surgery. 2013 Nov 1;22(4):195–8.
3. Staub E, Bolisetty S, Allegaert K, Raaijmakers A. Neonatal Kidney Function, Injury and Drug Dosing: A Contemporary Review. Children. 2025;12(3):339.
4. Poudel DR, Basnet S, Shrestha LP. Incidence, Risk Factors and outcome of neonatal acute kidney injury: an observational study. Journal of Institute of Medicine Nepal. 2022;44(2):1–6.
5. Charlton JR, Boohaker L, Askenazi D, Brophy PD, Fuloria M, Gien J, et al. Late onset neonatal acute kidney injury: results from the AWAKEN Study. Pediatric research. 2019;85(3):339–48.
6. Vikrant S, Gupta D, Singh M. Epidemiology and outcome of acute kidney injury from a tertiary care hospital in India. Saudi Journal of Kidney Diseases and Transplantation. 2018;29(4):956–66.
7. Yang L. Acute kidney injury in Asia. Kidney diseases. 2016;2(3):95–102.
8. Nada A, Bonachea EM, Askenazi D. Acute kidney injury in the fetus and neonate. Semin Fetal Neonatal Med. 2017 Apr;22(2):90–7.
9. Bueva A, Guignard JP. Renal function in preterm neonates. Pediatric research. 1994;36(5):572–7.
10. Miah MAS, Hasan AS, Khan MAH, Paul SK, Gupta SD, Alom MK, et al. Association of Neonatal AKI with Gestational Age and Birth Weight in Tertiary Care Hospitals of Dhaka City, Bangladesh. Sir Salimullah Medical College Journal. 2023;31(2):73–8.
11. Adugna DG. Prevalence and associated risk factors of preterm birth among neonates in referral hospitals of Amhara Region, Ethiopia. Plos one. 2022;17(10):e0276793.
12. Bruel A, Rozé JC, Flamant C, Simeoni U, Roussey-Kesler G, Allain-Launay E. Critical Serum Creatinine Values in Very Preterm Newborns. PLoS One. 2013 Dec 30;8(12):e84892.
13. Kamianowska M, Szczepański M, Wasilewska A. Tubular and glomerular biomarkers of acute kidney injury in newborns. Current drug metabolism. 2019;20(5):332–49.
14. Zhang Y, Zeng HH. Renal function profiles in preterm neonates with birth asphyxia within the first 24 H of life. Frontiers in Pediatrics. 2020;8:583540.
15. Iacobelli S, Guignard JP. Renal aspects of metabolic acid–base disorders in neonates. Pediatr Nephrol. 2020 Feb;35(2):221–8.
16. Schell-Feith EA, Kist-van Holthe JE, Van Der Heijden AJ. Nephrocalcinosis in preterm neonates. Pediatr Nephrol. 2010 Feb;25(2):221–30.

17. Jetton JG, Boohaker LJ, Sethi SK, Wazir S, Rohatgi S, Soranno DE, et al. Incidence and outcomes of neonatal acute kidney injury (AWAKEN): a multicentre, multinational, observational cohort study. Lancet Child Adolesc Health. 2017 Nov;1(3):184–94.
18. Yadav S, Lee B. Neonatal Respiratory Distress Syndrome. In: StatPearls [Internet]. Treasure Island (FL): StatPearls Publishing; 2025 [cited 2025 Jun 1]. Available from: http://www.ncbi.nlm.nih.gov/books/NBK560779/
19. Getaneh FB, Moges N, Mihretie DB, Bitew ZW. Time to recovery and predictors among admitted preterm neonates in the neonatal intensive care units of public hospitals of Addis Ababa, Ethiopia, 2021. BMC Pediatr. 2024 Jul 15;24(1):452.
20. Gupta S, Gaur BK, Jain R, Singh RR. Incidence, Risk Factors, and Outcomes of Acute Kidney Injury in Preterm Neonates Hospitalized in the Neonatology Unit, North India: A Single-center Experience. Saudi J Kidney Dis Transpl. 2023 Nov 1;34(6):592–601.
21. Monzani A. Determinants of renal function in preterm newborns. 2018 [cited 2025 Jun 1]; Available from: https://iris.uniupo.it/handle/11579/103279
22. Gallo D, de Bijl-Marcus KA, Alderliesten T, Lilien M, Groenendaal F. Early acute kidney injury in preterm and term neonates: incidence, outcome, and associated clinical features. Neonatology. 2021;118(2):174–9.