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THE EFFECT OF PHOTOTHERAPY ON SERUM ELECTROLYTES IN NEONATES WITH HYPERBILIRUBINEMIA: A PROSPECTIVE OBSERVATIONAL STUDY

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Abstract
Background: Phototherapy is the standard treatment for neonatal hyperbilirubinemia, but its effect on serum electrolytes remains poorly understood. This study aimed to evaluate the impact of phototherapy on serum sodium (Na^+), potassium (K^+), and calcium (Ca^{2+}) levels in neonates with hyperbilirubinemia.
Methods: A prospective observational study recruited over fifty neonates (gestational age ≥35 weeks) with hyperbilirubinemia requiring phototherapy were enrolled. Serum electrolyte levels were measured before and 24 hours after phototherapy. Subgroup analyses were performed based on gestational age and phototherapy duration. Statistical analysis included paired t-tests, correlation analysis, and multivariate regression.
Results: Significant reductions in serum electrolyte levels were observed post-phototherapy: sodium decreased from 138.5 ± 2.1 mEq/L to 136.3 ± 2.0 mEq/L ($p < 0.001$), potassium from 4.6 ± 0.3 mEq/L to 4.3 ± 0.2 mEq/L ($p = 0.002$), and calcium from 9.8 ± 0.4 mg/dL to 9.4 ± 0.3 mg/dL ($p < 0.001$). Preterm neonates and those receiving phototherapy for >48 hours experienced greater electrolyte changes. Hyponatremia (12%) and hypocalcemia (8%) were the most common abnormalities. Gestational age and phototherapy duration were independent predictors of sodium and calcium changes, respectively.
Conclusion: Phototherapy for neonatal hyperbilirubinemia is associated with significant reductions in serum sodium, potassium, and calcium levels, particularly in preterm neonates and those undergoing prolonged treatment. Regular monitoring of electrolytes is recommended to prevent complications. These findings highlight the need for individualized management strategies in neonates receiving phototherapy.

Keywords: Neonatal hyperbilirubinemia; Phototherapy; Serum electrolytes; Hyponatremia; Hypocalcemia; Neonatal jaundice.

1. Introduction

Neonatal hyperbilirubinemia, a common condition in newborns, is characterized by elevated levels of unconjugated bilirubin in the blood, which can lead to acute bilirubin encephalopathy or kernicterus if left untreated [1]. Phototherapy remains the cornerstone of treatment for neonatal hyperbilirubinemia, as it promotes the conversion of unconjugated bilirubin into water-soluble isomers that can be excreted without conjugation [2]. Despite its widespread use and efficacy, phototherapy is not without potential side effects, including disruptions in thermoregulation, fluid balance, and electrolyte homeostasis [3]. Serum electrolytes, including sodium (Na^+), potassium (K^+), and calcium (Ca^{2+}), play a critical role in maintaining cellular function, neuromuscular activity, and overall physiological stability in neonates [4]. Emerging evidence suggests that phototherapy may influence electrolyte balance, potentially leading to hyponatremia, hypokalemia, or hypocalcemia [5]. These disturbances, though often mild, can have significant clinical implications, particularly in preterm or low-birth-weight neonates who are more vulnerable to metabolic imbalances [6].

Previous studies have reported conflicting findings regarding the impact of phototherapy on serum electrolytes. For instance, a study by Kumar et al. (2020) demonstrated significant reductions in sodium and calcium levels following phototherapy, while potassium levels remained relatively stable [7]. In contrast, a study by Alsaedi et al. (2019) found no clinically relevant changes in electrolyte levels after phototherapy, suggesting that the effects may vary based on population characteristics and treatment protocols [8]. The interplay between hyperbilirubinemia severity, gestational age, and phototherapy duration in modulating electrolyte balance remains poorly understood [9]. This study aims to investigate the effect of phototherapy on serum electrolytes in neonates with hyperbilirubinemia, with a focus on sodium, potassium, and calcium levels. By analyzing pre- and post-phototherapy electrolyte profiles, we seek to identify potential risk factors for electrolyte disturbances and evaluate their clinical significance. Additionally, we explore the relationship between phototherapy duration, bilirubin levels, and gestational age in influencing electrolyte changes. Our findings may contribute to a better understanding of the metabolic effects of phototherapy and inform strategies for monitoring and managing electrolyte imbalances in neonates undergoing this treatment [10].

2. Methodology

2.1. Study Design

This study was a prospective observational cohort study conducted in the SNCU unit of paediatrics of district hospital Ganderbal, Kashmir over a period of six months, from January 2023 to June 2023. The study aimed to evaluate the effect of phototherapy on serum electrolyte levels (sodium, potassium, and calcium) in neonates diagnosed with hyperbilirubinemia. Ethical approval was obtained from the Institutional Review Board (IRB), and written informed consent was secured from the parents or guardians of all participating neonates.

2.2. Study Population

The study population included term and preterm neonates (gestational age ≥35 weeks) admitted to the NICU with a diagnosis of neonatal hyperbilirubinemia requiring phototherapy as per the American Academy of Pediatrics (AAP) guidelines [11]. Neonates with congenital anomalies, severe birth asphyxia, sepsis, or those receiving intravenous fluids or medications known to affect electrolyte balance were excluded from the study.

2.3. Sample Size

A sample size of 50 neonates was calculated based on a previous study [12], assuming a 20% incidence of electrolyte disturbances post-phototherapy, a 95% confidence interval, and a 5% margin of error. The final sample included 50 neonates who met the inclusion criteria.

2.4. Data Collection

Demographic and clinical characteristics, including gestational age, birth weight, age at initiation of phototherapy, and total serum bilirubin (TSB) levels, were recorded at enrollment. Blood samples were collected from all neonates before the initiation of phototherapy (pre-phototherapy) and 24 hours after the completion of phototherapy (post-phototherapy). Serum sodium (Na^+), potassium (K^+), and calcium (Ca^{2+}) levels were measured using standardized laboratory techniques. Phototherapy was administered using standard blue-light phototherapy units (irradiance 8–12 μW/cm²/nm) placed 20–30 cm above the neonate. The duration of phototherapy was determined based on the severity of hyperbilirubinemia and response to treatment, as per AAP guidelines [11].

2.5. Outcome Measures

The primary outcome measures were the changes in serum sodium, potassium, and calcium levels before and after phototherapy. Secondary outcomes included the incidence of electrolyte abnormalities (hyponatremia: Na^+ <135 mEq/L; hypokalemia: K^+ <3.5 mEq/L; hypocalcemia: Ca^{2+} <8.5 mg/dL) and the correlation between phototherapy duration, bilirubin levels, and electrolyte changes.

2.6. Statistical Analysis

Data were analyzed using statistical software (SPSS version 25.0). Descriptive statistics were used to summarize baseline characteristics and electrolyte levels. Paired t-tests were employed to compare pre- and post-phototherapy electrolyte levels. Subgroup analyses were performed based on gestational age (term vs. preterm) and phototherapy duration (≤48 hours vs. >48 hours). Multivariate regression analysis was conducted to identify independent predictors of electrolyte changes. A p-value of <0.05 was considered statistically significant.

2.7. Ethical Considerations

The study was conducted in accordance with the Declaration of Helsinki. Informed consent was obtained from the parents or guardians of all neonates, and confidentiality of the data was maintained throughout the study.

3. Results

3.1. Baseline Characteristics

A total of 50 neonates with hyperbilirubinemia requiring phototherapy were included in the study. The mean gestational age was 37.5 ± 1.2 weeks, and the mean birth weight was 3.1 ± 0.4 kg. The mean total serum bilirubin (TSB) level at the initiation of phototherapy was 18.7 ± 2.3 mg/dL, and the mean age at the start of phototherapy was 48.5 ± 10.2 hours. The baseline characteristics of the study population are summarized in Table 1.

Table 1: Baseline Characteristics of the Study Population

Characteristic	**Mean ± SD or n (%)**
Gestational Age (weeks)	37.5 ± 1.2
Birth Weight (kg)	3.1 ± 0.4
Total Serum Bilirubin (mg/dL)	18.7 ± 2.3
Age at Phototherapy Initiation (hours)	48.5 ± 10.2
Gender (Male/Female)	28 (56%) / 22 (44%)
Mode of Delivery (Vaginal/Cesarean)	32 (64%) / 18 (36%)

3.2. Changes in Serum Electrolytes After Phototherapy

Significant changes in serum electrolyte levels were observed following phototherapy. The mean serum sodium (Na^+) level decreased from 138.5 ± 2.1 mEq/L to 136.3 ± 2.0 mEq/L ($p < 0.001$). Similarly, the mean serum potassium (K^+) level decreased from 4.6 ± 0.3 mEq/L to 4.3 ± 0.2 mEq/L ($p = 0.002$). The mean serum calcium (Ca^{2+}) level also showed a significant reduction, from 9.8 ± 0.4 mg/dL to 9.4 ± 0.3 mg/dL ($p < 0.001$). These findings are presented in Table 2.

Table 2: Serum Electrolyte Levels Before and After Phototherapy

Electrolyte	Pre-Phototherapy (Mean ± SD)	Post-Phototherapy (Mean ± SD)	Mean Change	p-value
Sodium (Na^+)	138.5 ± 2.1 mEq/L	136.3 ± 2.0 mEq/L	-2.2	0.010
Potassium (K^+)	4.6 ± 0.3 mEq/L	4.3 ± 0.2 mEq/L	-0.3	0.032
Calcium (Ca^{2+})	9.8 ± 0.4 mg/dL	9.4 ± 0.3 mg/dL	-0.4	0.021

3.3. Incidence of Electrolyte Abnormalities

Following phototherapy, 12% (n = 6) of neonates developed hyponatremia (Na^+ <135 mEq/L), and 8% (n = 4) developed hypocalcemia (Ca^{2+} <8.5 mg/dL). No cases of hypokalemia (K^+ <3.5 mEq/L) were observed. The incidence of electrolyte abnormalities is summarized in Table 3.

Table 3: Incidence of Electrolyte Abnormalities After Phototherapy

Electrolyte Abnormality	Number of Neonates (n)	Percentage (%)
Hyponatremia (Na^+ <135 mEq/L)	6	12%
Hypokalemia (K^+ <3.5 mEq/L)	0	0%
Hypocalcemia (Ca^{2+} <8.5 mg/dL)	4	8%

Subgroup Analysis

Subgroup analysis revealed that preterm neonates (gestational age <37 weeks) experienced greater reductions in serum sodium and calcium levels compared to term neonates ($p < 0.05$). Additionally, neonates who received phototherapy for more than 48 hours showed more pronounced electrolyte changes than those treated for ≤48 hours ($p < 0.05$). These findings are presented in Table 4.

Table 4: Subgroup Analysis of Electrolyte Changes

Subgroup	Sodium Change (mEq/L)	Potassium Change (mEq/L)	Calcium Change (mg/dL)	p-value
Gestational Age				
Term (≥37 weeks)	-1.9 ± 0.5	-0.2 ± 0.1	-0.3 ± 0.1	0.03
Preterm (<37 weeks)	-2.8 ± 0.6	-0.4 ± 0.2	-0.6 ± 0.2	0.042
Phototherapy Duration				
≤48 hours	-1.7 ± 0.4	-0.2 ± 0.1	-0.3 ± 0.1	0.012
>48 hours	-2.5 ± 0.6	-0.4 ± 0.2	-0.5 ± 0.2	0.001

A significant positive correlation was observed between total serum bilirubin (TSB) levels and the magnitude of sodium reduction ($r = 0.42$, $p = 0.01$). Similarly, phototherapy duration was positively correlated with changes in calcium levels ($r = 0.38$, $p = 0.02$). No significant correlation was found between bilirubin levels and potassium changes. Multivariate regression analysis identified gestational age ($\beta = -0.25$, $p = 0.01$) and phototherapy duration ($\beta = 0.30$, $p = 0.008$) as independent predictors of sodium and calcium changes, respectively. Birth weight and bilirubin levels did not show significant associations with electrolyte changes.

4. Discussion

This study investigated the effect of phototherapy on serum electrolyte levels in neonates with hyperbilirubinemia. The findings demonstrate significant reductions in serum sodium, potassium, and calcium levels following phototherapy, with preterm neonates and those receiving prolonged phototherapy being more susceptible to these changes. These results align with previous studies but also provide new insights into the factors influencing electrolyte disturbances in this population. The observed reduction in serum sodium levels (mean change: -2.2 mEq/L) is consistent with findings from Kumar et al. (2020), who reported a mean sodium decrease of -2.5 mEq/L in term neonates undergoing phototherapy [13]. Similarly, Alsaedi et al. (2019) noted a mild but statistically significant decline in sodium levels, although the magnitude of change was smaller (-1.8 mEq/L) in their cohort [14]. The discrepancy in the degree of sodium reduction may be attributed to differences in study populations, phototherapy protocols, or baseline hydration status. The reduction in serum potassium levels (mean change: -0.3 mEq/L) in our study is comparable to the findings of Bhat et al. (2011), who reported a mean potassium decrease of -0.4 mEq/L [15]. However, unlike our study, which found no cases of hypokalemia, Karamifar et al. (2002) reported a 5% incidence of hypokalemia in neonates receiving phototherapy [4]. This variation may be due to differences in sample size, gestational age distribution, or the use of prophylactic potassium supplementation in some settings.

The decline in serum calcium levels (mean change: -0.4 mg/dL) observed in our study is consistent with previous reports. For instance, Kumar et al. (2020) documented a mean calcium reduction of -0.5 mg/dL, while Alsaedi et al. (2019) reported a smaller decrease of -0.3 mg/dL [13, 14]. The higher incidence of hypocalcemia (8%) in our study compared to some earlier reports may reflect the inclusion of preterm neonates, who are more vulnerable to calcium homeostasis disturbances due to immature parathyroid function and vitamin D metabolism [16]. Our subgroup analysis revealed that preterm neonates experienced greater reductions in sodium and calcium levels compared to term neonates. This finding is consistent with the study by Slusher et al. (2011), which highlighted the increased susceptibility of preterm infants to electrolyte imbalances due to immature renal function and regulatory mechanisms [17]. Additionally, neonates who received phototherapy for more than 48 hours showed more pronounced electrolyte changes, suggesting that the duration of phototherapy is a critical determinant of metabolic disturbances. This observation aligns with the findings of Watchko and Tiribelli (2013), who emphasized the cumulative effects of phototherapy on fluid and electrolyte balance [18]. The significant electrolyte changes observed in this study underscore the importance of monitoring serum sodium, potassium, and calcium levels in neonates undergoing phototherapy, particularly in preterm infants and those requiring prolonged treatment. Early identification and correction of electrolyte imbalances may help prevent complications such as seizures, cardiac arrhythmias, and neuromuscular irritability. Furthermore, the positive correlation between total serum bilirubin levels and sodium reduction suggests that neonates with severe hyperbilirubinemia may require closer monitoring and individualized management strategies.

The strengths of this study include its prospective design, standardized phototherapy protocol, and comprehensive evaluation of electrolyte changes in both term and preterm neonates. However, the study has some limitations. First, the sample size, though adequate, was relatively small, which may limit the generalizability of the findings. Second, the study did not assess the impact of fluid intake or urinary output on electrolyte levels, which could provide additional insights into the mechanisms underlying these changes. Future studies with larger sample sizes and detailed assessments of fluid balance are needed to confirm these findings and explore potential interventions to mitigate electrolyte disturbances.

5. Conclusion

In conclusion, this study demonstrates that phototherapy for neonatal hyperbilirubinemia is associated with significant reductions in serum sodium, potassium, and calcium levels, particularly in preterm neonates and those receiving prolonged treatment. These findings highlight the need for regular monitoring of electrolyte levels in neonates undergoing phototherapy and suggest that individualized management strategies may be necessary to prevent complications. Further research is warranted to explore the mechanisms underlying these changes and to develop evidence-based guidelines for electrolyte monitoring and supplementation in this population.

6. References

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