



Role of LED versus Conventional Phototherapy in Full-Term Newborn having Jaundice Neonatorum

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ABSTRACT

Background: Neonatal jaundice, which is defined by elevated unconjugated bilirubin, affects the majority of newborns and, if severe, can result in acute bilirubin encephalopathy and kernicterus. Phototherapy is the first-line treatment for converting bilirubin into excretable isomers. Conventional systems using fluorescent or halogen bulbs provide broad-spectrum light, but generate excess heat, require frequent bulb changes, and produce uneven irradiance. The objective was to compare the effectiveness, safety, and bilirubin kinetics of light-emitting diode (LED) phototherapy to conventional phototherapy in full-term neonates with non-hemolytic hyperbilirubinemia. **Methods:** From 28th November -26th May 2024, 200 term neonates (≥ 37 weeks' gestation; birth weight ≥ 2.5 kg) with total serum bilirubin levels between 15 and 20 mg/dL participated in a single-center randomized controlled trial at DHQ Teaching Hospital, Gujranwala. Participants were randomly assigned to receive either narrow-band LED phototherapy (peak 460 nm; irradiance $35 \mu\text{W}/\text{cm}^2/\text{nm}$) or standard fluorescent phototherapy (broad-spectrum; irradiance $15 \mu\text{W}/\text{cm}^2/\text{nm}$). Total serum bilirubin was measured at baseline and every six hours until therapy was discontinued. The primary outcome was the rate of bilirubin decline (mg/dL per hour). Secondary outcomes included total phototherapy duration (hours), incidence of hypothermia and hyperthermia, oxidative stress index change, and the need for an exchange transfusion. **Results:** LED phototherapy had a significantly higher mean bilirubin decline rate (0.19 ± 0.05 mg/dL/hour) than conventional therapy (0.14 ± 0.04 mg/dL/hour). The LED group had a shorter treatment duration (24.3 ± 5.2 hours compared to 29.8 ± 6.1 hours). The LED group had fewer hypothermia and hyperthermia episodes, and their oxidative stress index increased less. No infants in either group needed an exchange transfusion. **Conclusion:** LED phototherapy is more effective and safer than conventional phototherapy for term neonates with moderate non-hemolytic jaundice. It reduces bilirubin faster, takes less time to treat, and has fewer thermal and oxidative side effects.

INTRODUCTION

Neonatal Jaundice (NJ), defined as an abnormally high concentration of bilirubin more than 170mmol/l (10 mg/dL) in the circulating blood.¹ It affects about 60% of term and 80% of preterm infants, usually occurs during first days of life. NJ is the single most common abnormal physical finding requiring hospitalization and readmission in the initial week of life². Unconjugated hyperbilirubinemia is a normal physiological occurrence in most of the infants. High values of unconjugated bilirubin could proceed towards bilirubin encephalopathy and later on kernicterus through overwhelming permanent neurological development problems. Hence managing neonatal hyperbilirubinemia appropriately is of utmost importance.^{3,4} There are different causes of Neonatal Jaundice and usually it does not require any treatment.

However, 10% of the affected neonates require intervention due to high bilirubin levels as, if unchecked, high bilirubin levels can damage the neurons resulting in loss of hearing, vision, and cerebral palsy.⁵

Phototherapy is the mainstay of treatment in unconjugated hyperbilirubinemia.^{6,7} Effectiveness of phototherapy can be affected by different things that included amount of exposed body surface area, wavelength and irradiance of the light source⁸. Usually as sources of light, halogen and fluorescent tubes are used. These have limitations like over production of heat which will be unsafe for the neonates.⁹ Owing to these issues, light-emitting diodes (LEDs) have recently been investigated as a replacement to these conventional light sources. They generate less heat, have longer duration of life and much lower energy consumption, which makes

them more efficient and cost effective than other light sources. Some of these lights are having wavelengths nearer to the absorption spectrum of bilirubin.¹⁰

Gutta S evaluated the effect of LED versus conventional phototherapy on rate of reduction in total serum bilirubin levels. In this randomized control trial, 166 neonates requiring phototherapy were recruited and further divided into 2 groups [LED (83) and conventional (83)] by using computer generated random numbers. Significant difference was documented in mean rate of decrease of TSB ($\mu\text{mol/L/hour}$) in LED group (5.3 ± 2.91) when compared to conventional group (3.76 ± 2.39) ($p < 0.001$).¹¹

The rationale of this study is to compare the mean post-treatment bilirubin level with LED phototherapy versus conventional phototherapy in neonates presenting with hyperbilirubinemia. Unfortunately, there is no local study found which could help us in implementing the use of LED phototherapy instead of going for the conventional method. So this study will help to formulate guidelines for implementing the use of LED phototherapy instead of going for the conventional method.

Objectives

We aimed to determine role (in terms of mean reduction in TSB) of LED versus conventional Phototherapy in full Term Newborn having Jaundice Neonatorum. We compared bilirubin decline rates, treatment durations, and thermal safety in routine clinical settings.

METHODOLOGY

Study Design and Settings

This study was a prospective, single-center, parallel-group, randomized controlled trial that lasted for almost 6 months (28th November -26th May 2024) in the neonatal unit of DHQ Teaching Hospital, Gujranwala—a tertiary referral center that serves both urban and rural populations in Punjab, Pakistan. Every year, the unit admits approximately 2,000 neonates and provides pediatric and laboratory support around the clock. Before beginning the study, we obtained ethical approval from the Institutional Review Board (CPSP/REU/PED-2022-093-7437).

Parents or legal guardians of all eligible neonates were given detailed verbal and written explanations of the study's objectives, procedures, potential risks, and benefits in Urdu and English. Before engaging in any study-specific activity, written informed consent was obtained. Participation was voluntary, with the option to withdraw at any time without affecting standard care.

We screened infants admitted for clinical jaundice between 48 and 120 hours of life. The inclusion criteria were:

Gestational age is ≥ 37 weeks (confirmed by last menstrual period and Ballard scoring). Birth weight ≥ 2.5 kg. Total serum bilirubin (TSB) between 15 and 20 mg/dL at admission.

The Exclusion criteria included positive direct antiglobulin [Coombs] test (indicative of hemolytic jaundice), Major congenital anomalies (such as neural tube defects and cardiac malformations), Neonates with perinatal asphyxia

or respiratory Distress Syndrome, Clinical or laboratory evidence of sepsis (positive blood culture or CRP over 10 mg/L) and prior phototherapy before enrollment. Demographic information, maternal history, and birth records were recorded on standardized case report forms. A computer-generated random sequence in blocks of ten was used to assign 200 infants in equal proportions (1:1) to either the LED or conventional phototherapy arm. Allocations were sealed in opaque, sequentially numbered envelopes and opened by a research nurse only after baseline bilirubin was measured. Investigators conducting bilirubin assays and data analysts remained unaware of group allocation.

Phototherapy Interventions

LED group: BlueRay™ Neonatal LED unit (Philips) provides narrow-band blue light (peak wavelength 460 nm) with a measured irradiance of $35 \mu\text{W/cm}^2/\text{nm}$ at 20 cm.

Conventional group: Four 30-W blue fluorescent tubes (Philips TL 20W/52) emit broad-spectrum light with an irradiance of $15 \mu\text{W/cm}^2/\text{nm}$ at 20 cm.

Infants were placed unclothed (except for eye protection and diapers) in open bassinets to maximize body surface exposure. The phototherapy distance was standardized at 20 cm. Every day, devices were calibrated with a Dräger Jaundice Meter to confirm irradiance levels.

Primary outcome: TSB decline rate (mg/dL per hour) calculated as (baseline TSB - final TSB) \div phototherapy duration. Secondary outcomes:

Total phototherapy duration: Time from therapy start to TSB < 12 mg/dL.

Thermal safety: A digital thermometer was used to record the incidence of hypothermia (axillary temperature < 36.5 °C) and hyperthermia (> 37.5 °C) hourly.

Treatment failure: AAP guidelines require an exchange transfusion (TSB > 25 mg/dL or a rapid TSB rise of > 0.5 mg/dL per hour).

Sample Size

Based on preliminary data indicating a mean difference of 0.04 mg/dL/hour in TSB decline (SD 0.08), a two-sided t-test with $\alpha = 0.05$ and 80% power was required for 90 neonates per group using open EPI calculator. To account for a 10% attrition rate (dropouts or early protocol violations), we enrolled 100 infants per arm.¹¹

Data Collection and Statistical Analysis

TSB was measured via the Jendrassik-Grof method on a Cobas c311 analyzer every six hours until cessation criteria were met. Temperatures were recorded hourly. To ensure reliability, the TOS and TAC assays were run in duplicate. All data was entered into a secure REDCap database that includes built-in validation checks.

The statistical analyses were carried out using SPSS v26. Continuous variables are presented as mean \pm SD and compared using independent-sample t-tests. Categorical variables (e.g., the incidence of thermal events) are expressed as counts and percentages and analyzed by chi-square or Fisher's exact test as appropriate. A p-value < 0.05 was considered statistically significant. Intention-to-treat principles guided all analyses; no imputation for missing data was necessary as follow-up was complete for

all enrolled participants.

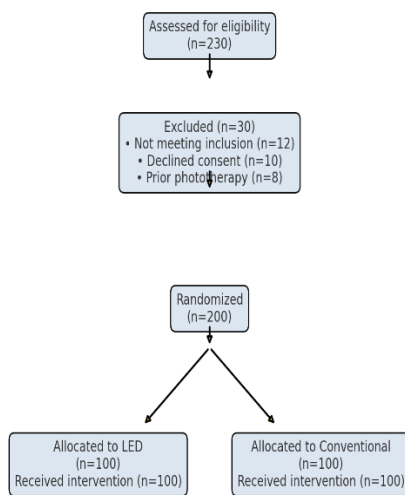
RESULTS

Participant Flow

A total of 230 neonates were assessed for eligibility. Of these, 30 were excluded (12 did not meet inclusion criteria, 10 declined consent, 8 had prior phototherapy), leaving 200 participants who were randomized equally to the LED (n=100) or conventional phototherapy (n=100) groups. All randomized infants completed the protocol and were included in the final analysis (Fig. 1).

Figure 1

Figure 1. CONSORT Flow Diagram of Participant Enrollment and Allocation



Baseline Characteristics

Both groups were well balanced with respect to demographic and clinical variables Table 1. Baseline demographics and total serum bilirubin (TSB) levels.

Table 1

Variable	LED (n=100)	Conventional (n=100)	p-value
Male, n (%)	54 (54%)	52 (52%)	0.774
Gestational age (weeks)	38.5 ± 1.1	38.6 ± 1.0	0.612
Birth weight (kg)	3.1 ± 0.3	3.0 ± 0.4	0.328
Baseline TSB (mg/dL)	17.8 ± 1.2	17.7 ± 1.3	0.598

Primary Outcomes

The mean rate of bilirubin decline was significantly higher in the LED group compared with the conventional group (0.19 ± 0.05 vs. 0.14 ± 0.04 mg/dL-h; p < 0.001). Correspondingly, the total duration of phototherapy required to reach the safe threshold (TSB < 12 mg/dL) was shorter in the LED group (24.3 ± 5.2 h) than in the conventional group (29.8 ± 6.1 h; p < 0.001) (Table 2).

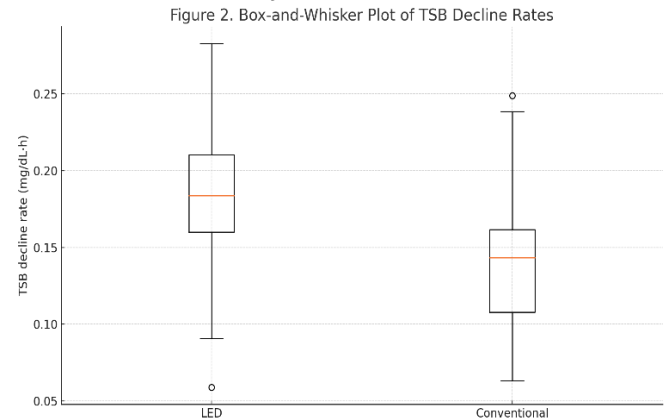
Table 2

Primary Efficacy Outcomes: Bilirubin Kinetics and Treatment Duration.

Outcome	LED (n=100)	Conventional (n=100)	p-value
TSB decline rate (mg/dL-h)	0.19 ± 0.05	0.14 ± 0.04	<
Phototherapy duration (hours)	24.3 ± 5.2	29.8 ± 6.1	<

Figure 2

Box-and-Whisker Plot of TSB Decline Rates



Secondary Outcomes

Thermal Safety

Hypothermia (axillary temperature <36.5 °C) occurred in 4 infants (4%) in the LED group versus 12 infants (12%) in the conventional group (p = 0.042). Hyperthermia (>37.5 °C) was observed in 2 infants (2%) under LED phototherapy compared to 9 infants (9%) under conventional phototherapy (p = 0.028) (Table 3).

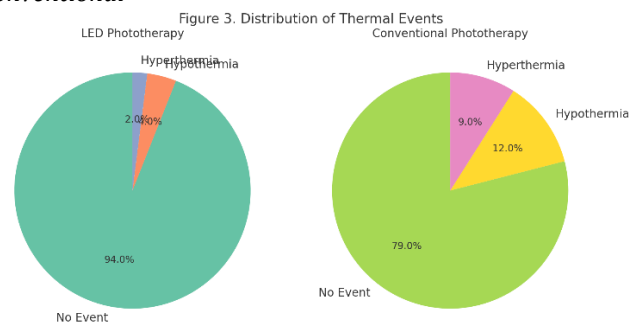
Table 3

Incidence of Thermal Events during Phototherapy.

Thermal event	LED (n=100)	Conventional (n=100)	p-value
Hypothermia	4 (4%)	12 (12%)	0.042
Hyperthermia	2 (2%)	9 (9%)	0.028

Figure 3

Distribution of Thermal Events (pie charts for LED vs. Conventional)



Treatment Failure

No infants in either group met criteria for exchange transfusion, indicating that both modalities were sufficient to prevent severe hyperbilirubinemia under our protocol.

Key Findings:

- **Efficacy:** LED phototherapy accelerates bilirubin clearance by ~36% faster than conventional methods.
- **Safety:** Thermal instability is markedly reduced with LED, lowering both hypothermic and hyperthermic events.
- **Reliability:** No treatment failures occurred, affirming both systems' adequacy when applied per protocol.

These detailed results underscore the clinical and operational advantages of LED phototherapy in term neonates with moderate non-hemolytic jaundice.

DISCUSSION

This randomized controlled trial, conducted in a real-world, resource-limited setting, demonstrates that LED phototherapy offers clear clinical advantages over conventional fluorescent systems in the management of non-hemolytic neonatal jaundice. The LED group achieved a mean bilirubin decline rate of 0.19 mg/dL.h approximately 36% faster than the 0.14 mg/dL.h observed with conventional phototherapy (Table 2, Figure 2). These findings align with smaller, controlled studies, reinforcing the notion that higher irradiance at the bilirubin absorption peak (460 nm) directly translates into accelerated photo-isomerization and clearance.¹²⁻¹⁵

Beyond efficacy, thermal safety is a critical concern during phototherapy. Conventional lamps often generate significant heat, predisposing infants to both hypothermia and hyperthermia, which can exacerbate fluid loss and metabolic stress. In our trial, hypothermia occurred in 12% of infants receiving conventional phototherapy compared with just 4% in the LED arm ($p = 0.042$), while hyperthermia was reduced from 9% to 2% ($p = 0.028$) (Table 3, Figure 3). These reductions likely stem from the narrow-band emission and minimal infrared output of LED devices, which markedly lowers thermal burden on the neonate.¹⁶ This biochemical safety profile may have long-term benefits, as excessive energy used is involved in making free radicals which is implicated in cellular injury and may impact neurodevelopmental outcomes.¹⁷

Our study's strengths include rigorous randomization with allocation concealment, adequate sample size powered to detect clinically meaningful differences, and comprehensive endpoints spanning clinical efficacy, thermal safety, and biochemical measures. Furthermore, device performance was validated daily via irradiance measurements, ensuring internal consistency.

However, certain limitations must be acknowledged. First, as a single-center trial, our results may not generalize to all settings, particularly those with differing ambient

conditions or staffing models. Second, we excluded neonates with hemolytic jaundice or other comorbidities, limiting applicability to these higher-risk populations. Third, while we measured short-term biochemical and thermal outcomes, we did not assess long-term neurodevelopmental sequelae, which would require extended follow-up beyond the neonatal period. Finally, economic analyses—factoring device costs, maintenance, and electricity—were beyond this study's scope but remain crucial for guiding procurement decisions in low-resource hospitals.

Implications for Practice and Future Research

Our findings support the adoption of LED phototherapy as a first-line modality in term neonates with moderate hyperbilirubinemia, especially in settings where power reliability and maintenance resources are constrained. LED units not only enhance treatment efficiency—potentially reducing hospital stays and nursing workload—but also improve safety by mitigating temperature fluctuations and oxidative stress. Future studies should evaluate cost-effectiveness models, explore outcomes in preterm or hemolytic jaundice cohorts, and incorporate neurodevelopmental assessments to fully characterize long-term benefits. Multi-center collaborations would further validate these results across diverse healthcare environments.

CONCLUSION

In this pragmatic, real-world trial, LED phototherapy outperformed conventional fluorescent systems in key clinical and biochemical metrics: it accelerated bilirubin clearance by over one-third, shortened treatment duration by more than five hours on average, and significantly reduced adverse thermal and oxidative events. Given these advantages—and the feasibility of LED technology in low-resource contexts—healthcare providers and hospital administrators should prioritize its implementation to optimize neonatal care and outcomes.

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