Double Surface LED Phototherapy as an Effective Alternative to Exchange Transfusion in Neonatal Jaundice

I Jahan[1], J Akter[2], T M Shetu[3], Z Sultana[4], B H N Yasmeen[5]

Abstract

Background: Neonatal jaundice is a common condition may progress to severe hyperbilirubinemia requiring exchange transfusion (ET). This study evaluates the efficacy and safety of double-surface LED phototherapy as a substitute for ET in clinically significant neonatal jaundice.

Methods: This retrospective observational study included 52 neonates admitted with neonatal jaundice to Bangladesh Specialized Hospital between July 2024 and January 2025. Patients were categorized based on whether they received single- or double-surface LED phototherapy. Data on bilirubin levels, treatment duration, complications, neurological outcomes, and ET requirement were collected and analyzed using SPSS version 25.

Results: Double-surface phototherapy was used in 67.3% of cases and led to a significantly higher bilirubin reduction within 24 hours (mean 8.80 ± 2.60 mg/dL) compared to single-surface therapy (3.36 ± 1.27 mg/dL; $p < 0.0001$). Hospital stay was shorter in the double-surface group (18.7 ± 6.24 vs. 56.4 ± 4.8 hours). Among 17 neonates with total serum bilirubin (TSB) ≥ 20 mg/dL, none required ET following double-surface phototherapy. No neurological abnormalities or severe complications were observed in either group.

Conclusion: Double-surface LED phototherapy is an effective, safe, and non-invasive treatment that can serve as a viable alternative to exchange transfusion for high-risk neonatal jaundice, especially in low-resource settings.

Keywords: Neonatal jaundice, Double-surface phototherapy, Exchange transfusion, Bilirubin reduction, LED phototherapy

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[1]Dr. Ishrat Jahan
Consultant
Dept. of Pediatrics and Neonatology
Bangladesh Specialized Hospital, Dhaka

[2]Dr. Jesmine Akter
Junior Consultant
Dept. of Pediatrics and Neonatology
Bangladesh Specialized Hospital, Dhaka

[3]Dr. Tanima Mahmud Shetu
Specialist
Neonatal Intensive Care Unit
Bangladesh Specialized Hospital, Dhaka

[4]Dr. Zakia Sultana
Registrar
Neonatal Intensive Care Unit
Bangladesh Specialized Hospital, Dhaka

[5]Prof. Dr. B H Nazma Yasmeen
Professor and Head
Dept. of Paediatrics
Northern International Medical College, Dhaka, Bangladesh

Correspondence
Prof. Dr. Ishrat Jahan
Consultant & Coordinator
Dept. of Pediatrics & Neonatology
Bangladesh Specialized Hospital, Dhaka, Bangladesh.

Introduction

Neonatal jaundice is a common physiological condition that affects approximately 60% of term and up to 80% of preterm newborns during the first week of life.[1,2] While most cases resolve spontaneously or with minimal intervention, a subset of neonates develop progressively rising serum bilirubin levels that pose a significant risk of bilirubin-induced neurologic dysfunction (BIND), including acute encephalopathy and kernicterus. Globally, neonatal hyperbilirubinemia remains a major contributor to neonatal morbidity and mortality, with an estimated 1.1 million infants affected annually, leading to over 114,000 deaths and approximately 63,000 cases of long-term neurodevelopmental impairment.[3] The burden of these preventable outcomes is disproportionately concentrated in low- and middle-income countries (LMICs), where delays in diagnosis and limited access to timely and effective treatment exacerbate clinical progression. South Asia and sub-Saharan Africa alone account for nearly three-quarters of all global deaths attributed to complications of neonatal jaundice.[4] In these regions, healthcare has various limitations—such as delayed postnatal follow-up, inadequate availability of high-intensity phototherapy units, and poorly equipped blood banks—which amplify the risk of adverse outcomes. In Bangladesh, neonatal jaundice continues to be a leading cause of hospital admission, with clinical management often complicated by hemolytic diseases, sepsis, or prematurity. A study conducted at a tertiary care center in Dhaka reported that among 839 neonates treated for jaundice, 4.9% eventually required exchange transfusion (ET) despite initiation of phototherapy, with blood group incompatibility and neonatal sepsis being the predominant underlying causes.[5]

These findings highlight the urgent need for more effective, scalable, and non-invasive treatment

options that can avert the need for ET in high-risk neonates. According to the 2022 guidelines issued by the American Academy of Pediatrics (AAP), phototherapy remains the cornerstone of treatment for neonatal hyperbilirubinemia, with therapeutic thresholds defined by gestational age, postnatal age in hours, and presence of risk factors.[6] Exchange transfusion is reserved for emergency cases—specifically when total serum bilirubin (TSB) approaches or exceeds critical thresholds, or when signs of acute bilirubin encephalopathy emerge.[7,8] While ET is highly effective in rapidly lowering serum bilirubin, it is an invasive procedure that requires extensive resources, including access to well-equipped blood banks and skilled neonatal care teams. Furthermore, ET carries considerable risk: complications such as thrombocytopenia (15–35%), hypocalcemia, hypoglycemia, catheter-related infections, cardiac arrhythmias, and procedure-related mortality (up to 1%) are well documented in both high-income and low-resource settings.[9-11]

Recent technological advancements in phototherapy offer promising alternatives to mitigate the need for invasive procedures like ET. Light-emitting diode (LED) phototherapy has emerged as a superior alternative to conventional compact fluorescent or halogen-based phototherapy due to its wavelength specificity (centered around 460–470 nm), lower thermal output, higher energy efficiency, and longer operational lifespan.[12] Notably, double surface LED phototherapy systems—designed to irradiate both the anterior and posterior surfaces of the neonate—deliver higher irradiance and expose a larger skin surface area to therapeutic light, thereby enhancing the photodegradation of unconjugated bilirubin. Several studies have demonstrated the clinical superiority of double surface LED phototherapy compared to single-surface and conventional units.

Hafidth et al. (2013) reported that neonates treated with double-surface phototherapy exhibited a ≥43% reduction in TSB within the first 12 hours, significantly higher than the 17% observed with single-surface phototherapy ($p < 0.001$).[13] Importantly, none of the neonates treated with double surface phototherapy required ET, even when their initial bilirubin levels were approaching exchange thresholds. Similarly, Arnolda et al. (2018) demonstrated a 54% faster bilirubin decline in the first 6 hours, a 45% higher overall rate of bilirubin clearance, and a 21% shorter treatment duration with double surface devices.[14] Case reports, such as that by Abe and Fujioka (2021), further support the potential of double surface LED phototherapy in stabilizing at-risk neonates and avoiding ET entirely.[15]

Observing this gap in Bangladesh and the high burden of jaundice-related complications in resource-constrained settings, there is a pressing need to evaluate the real-world effectiveness of double surface LED phototherapy in preventing ET. This study aims to assess whether double surface LED phototherapy, when applied early in neonates with clinically significant hyperbilirubinemia, can prevent progression to ET, reduce hospitalization duration and cost, and minimize the risk of treatment-related complications.

Methods

This retrospective observational study was conducted at Bangladesh Specialized Hospital, Dhaka, analyzing medical records from July 2024 to January 2025. A total of 52 neonates admitted with clinically significant neonatal jaundice who received either single- or double-surface LED phototherapy were included. Patients with incomplete bilirubin data or congenital anomalies were excluded. A structured data collection sheet was used to extract relevant variables including sex, gestational age (categorized), birth weight (categorized), mode of delivery, phototherapy type, total serum bilirubin (TSB) levels before and after 24 and 48 hours of therapy, day of life when phototherapy was started, duration of phototherapy, duration of hospital stay, complications, neurological status at discharge, survival outcome, and need for exchange transfusion. Among the selected participants, patients were divided into two groups. 35 neonates received double-surface LED phototherapy and 17 received single-surface phototherapy. The primary outcome was the reduction in TSB after 24 hours of phototherapy. Secondary outcomes included duration of hospital stay, complication frequency, and neurological condition at discharge. Statistical analyses were performed using SPSS version 25. Continuous variables were summarized as mean ± standard deviation and compared using independent or paired t-tests. Categorical variables were expressed as frequencies and analyzed with chi-square or Fisher's exact test. A p-value of <0.05 was considered statistically significant.

Results

A total of 52 neonates were included in the study. Of them, 27 (51.92%) were male and 25 (48.08%) were female. Regarding gestational age, 24 (46.15%) were preterm, 13 (25.00%) were late preterm, and 15 (28.85%) were term neonates. The majority of neonates had very low birth weight (40.38%), followed by low birth weight (26.92%) and normal birth weight (32.69%), with a mean birth weight of 2.08 kg. Most neonates were delivered by lower uterine cesarean section (LUCS) (71.15%), while 28.85% were delivered via normal vaginal delivery. (Table-I)

Table I. Baseline Characteristics of the Study Population (N = 52)

Characteristic	Frequency (n)	Percentage (%)
Sex		
Male	27	51.92%
Female	25	48.08%
Gestational Age Category		
Term	15	28.85%
Late Preterm	13	25.00%
Preterm	24	46.15%
Birth Weight Category		
Very Low Birth Weight	21	40.38%
Low Birth Weight	14	26.92%
Normal Birth Weight	17	32.69%
Mean Birth Weight	2.08 kg	
Mode of Delivery		
LUCS	37	71.15%
NVD	15	28.85%

Among the 52 neonates, 35 (67.31%) received double surface LED phototherapy, while 17 (32.69%) received single surface phototherapy. The mean duration of phototherapy was notably shorter in the double surface group (26.4 hours) compared to the single surface group (40.3 hours). Additionally, phototherapy was initiated earlier in the double surface group, with a mean day of life of 2.5, compared to 3.7 in the single surface group. (Table-II)

Table-II : Phototherapy Details Among Neonates

Type of Phototherapy	Frequency (n)	Percentage (%) (hours)	Mean Duration	Mean Day of Life Started
Double Surface	35	67.31%	26.4	2.5
Single Surface	17	32.69%	40.3	3.7

In the double surface phototherapy group, the mean total serum bilirubin (TSB) significantly decreased from 21.99 ± 1.84mg/dL to 13.19 ±1.80 mg/dL after 24 hours, with a mean reduction of 8.80 ±2.60 mg/dL ($p < 0.0001$). In comparison, the single surface group showed a reduction from 17.20 ±0.90 mg/dL to 13.84±0.90 mg/dL, with a mean reduction of 3.36 ± 1.27 mg/dL ($p < 0.0001$). The bilirubin reduction was substantially greater in the double surface group. (Table III)

Table III : Comparison of Total Serum Bilirubin Levels Before and After 24 Hours of Phototherapy

Phototherapy Type	TSB Before Phototherapy (Mean ± SD)	TSB After 24h Phototherapy (Mean ± SD)	TSB Reduction (Mean ± SD)	p-value (Before vs 24h)
Double Surface	21.99 ± 1.84	13.19 ± 1.80	8.80 ± 2.60	<0.0001
Single Surface	17.20 ± 0.90	13.84 ± 0.90	3.36 ± 1.27	<0.0001

Neonates treated with double surface phototherapy had a significantly shorter mean hospital stay (18.7 ± 6.24 hours) compared to those treated with single surface phototherapy (56.4 ± 4.8 hours). No immidimedate neurological abnormalities were detected in either group at the time of discharge.(Table-IV)

Table IV : Clinical Outcome by Phototherapy Type

Outcome	Double Surface (n=35)	Single Surface (n=17)
Mean Duration of Hospital Stay	18.7 ± 6.24 hours	56.4 ± 4.8 hours
Neurological Abnormalities		
No Abnormalities detected	35 (100%)	17 (100%)

The majority of neonates in both groups experienced no complications, with 77.14% in the double surface group and 76.47% in the single surface group remaining complication-free. Minor complications included frequent loose stools (8.57% in double surface vs. 11.76% in single surface), rash (8.57% vs. 5.88%), and dehydration (5.71% vs. 5.88%). No severe adverse events were reported in either group. (Table V)

Table V : Complications Reported Among Neonates

Complication Type	Double Surface (n=35)		Single Surface (n=17)	
	n	%	n	%
Frequent loose stool	3	8.57%	2	11.76%
Rash	3	8.57%	1	5.88%
Dehydration	2	5.71%	1	5.88%
No Complications	27	77.14%	13	76.47%

Among the 35 neonates who received double surface phototherapy, 17 had initial total serum bilirubin (TSB) levels ≥ 20 mg/dL—typically meeting criteria for potential exchange transfusion. However, none of these patients required the procedure following double surface phototherapy. In the single surface group, all 17 neonates had TSB levels < 20 mg/dL, and none required exchange transfusion either. (Table-VI)

Table VI : Potential Exchange Transfusion Requirement vs Actual Need

Phototherapy Type	Patients with TSB ≥ 20 mg/dL (n)	Patients with TSB < 20 mg/dL (n)	Exchange Transfusion Performed
Double Surface	17	18	None
Single Surface	0	17	None

Discussion

In the present cohort, nearly half of the neonates were preterm (46.2%) and 40.4% were classified as very low birth weight, which is in line with existing literature identifying these populations as high-risk for developing hyperbilirubinemia.[16,17] Caesarean delivery accounted for over 70% of cases, a trend consistent with reports indicating a high prevalence of jaundice among neonates delivered via LUCS in LMICs.[18]

Phototherapy was initiated earlier and administered for a significantly shorter duration in neonates receiving double-surface LED treatment, with a mean start day of life 2.5 and therapy duration of 26.4 hours, compared to day 3.7 and 40.3 hours in the single-surface group. This aligns with findings from Arnolda et al. and Al-Hafidth et al., both of which reported

shorter treatment duration and faster bilirubin decline with double-surface setups.[14,19] Specifically, Arnolda et al. documented a 21% shorter treatment duration and a 54% faster TSB decline within the first 6 hours in the double-surface group, while Al-Hafidth et al. found an average TSB reduction of 43.45% in the double-surface group versus 17.03% in the single-surface group after 24 hours.[14,19]

The current study demonstrated that double-surface LED phototherapy yielded a mean bilirubin reduction of 8.80 ± 2.60 mg/dL within 24 hours, more than double the 3.36 ± 1.27 mg/dL reduction observed in the single-surface group, with both changes being statistically significant. This is comparable to results reported by Sillapakitkosol, who found a significantly greater bilirubin reduction rate (0.17 mg/dL/h vs. 0.13 mg/dL/h) in neonates treated with adapted double-surface units.[20]

The enhanced irradiance and increased skin exposure offered by the double-surface configuration appear to accelerate photoconversion and facilitate faster bilirubin clearance. Notably, this efficiency translated into a shorter mean hospital stay for the double-surface group (18.7 ± 6.24 hours vs. 56.4 ± 4.8 hours), supporting reports from multiple studies including Arnolda et al. and Rouf et al., which demonstrated shorter stays and reduced healthcare utilization with LED phototherapy.[5,14]

These operational benefits hold considerable significance in resource-limited settings like Bangladesh, where prolonged hospitalization imposes short-term complications, along with financial and emotional burdens on families. Importantly, no neurological abnormalities were detected at discharge in either group, reaffirming the safety of double-surface LED phototherapy even at higher irradiance levels. This is consistent with findings from Sillapakitkosol, Abe and Fujioka, and Sherbiny et al., all of whom reported no increase in short-term neurological complications following intensive LED treatment.[15,20,21] Furthermore, adverse events such as rash, diarrhea, or dehydration were mild, infrequent, and statistically similar between groups in our study, supporting safety profiles reported by Sabzehei et al. and Kumar et al., where side effects were comparable or even lower in double-surface or LED-treated groups.[22,23]

The most significant finding was that all 17 neonates with TSB ≥ 20 mg/dL who received double-surface phototherapy avoided exchange transfusion, compared to none in the single-surface group reaching ET thresholds. This result echoes Al-Hafidth et al., where ET was avoided in all high-risk cases treated with double-surface LED but required in over 90% of conventional therapy cases.[19] Similarly, Abe and Fujioka presented a successful case of avoiding ET with double-LED treatment in a severely jaundiced neonate.[15]

Our study outcomes demonstrate that the double-surface LED phototherapy can serve as a viable substitute for ET in many high-risk neonates, significantly reducing the need for invasive interventions. In LMIC settings, where ET is often constrained by blood availability, personnel expertise, and infection risks, this modality offers a safer, cost-effective, and logistically simpler alternative.

Conclusion

The findings of this study demonstrate that double-surface LED phototherapy is a highly effective and clinically safe intervention for the management of neonatal jaundice, particularly in neonates at risk of requiring exchange transfusion. Compared to single-surface therapy, the double-surface modality facilitated significantly greater and faster reductions in total serum bilirubin, required shorter duration of treatment which was associated with a reduced number of days of hospital stay. Importantly, it completely eliminated the need for exchange transfusion in neonates with bilirubin levels ≥20 mg/dL, highlighting its potential as a non-invasive and resource-efficient substitute for more invasive procedures. The absence of neurological complications and the comparable incidence of minor adverse effects between the two groups further reinforce the safety of double-surface therapy. These findings are especially relevant in resource-limited settings where timely access to exchange transfusion is often constrained.

Recommendation

Based on the results of this study, it is recommended that double-surface LED phototherapy be prioritized as a first-line treatment for neonates with clinically significant hyperbilirubinemia, particularly those that are near to exchange transfusion thresholds. Implementation of this modality can significantly reduce the reliance on invasive procedures, lower hospital stays, minimize treatment-related complications, and reduce financial and logistical burdens for families and healthcare systems—especially in low- and middle-income countries.

Limitations Of The Study

This analysis was retrospective and single-centered, with a small sample, relied on short-term neurological assessment only, and showed unequal baseline TSB between groups. Prospective studies with larger, diverse cohorts and extended outcome surveillance will be needed to validate our findings.

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