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Original Article

Paediatrics Section

Effects of Different Types of Phototherapy Units on Neonatal Jaundice: A Cross-sectional Study

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ABSTRACT

Introduction: Phototherapy is the mainstay of treatment of neonates who develop significant jaundice. Light-emitting Diode (LED) and compact florescent lamp phototherapy units are the newer devices in the management of neonatal hyperbilirubinaemia. The advantage of LED phototherapy includes portability, energy efficiency, less heat production and durability. Blue and white phototherapy devices are more economical but generate more heat leading to hyperthermia and dehydration more often.

Aim: To determine the efficacy and side effects of three modes of phototherapy units viz conventional blue and white light phototherapy, Compact Fluorescent Lamp (CFL) phototherapy, and LED phototherapy on neonates having jaundice.

Materials and Methods: This cross-sectional study was conducted in Department of Paediatrics at SRM Medical College Hospital and Research Centre (tertiary care teaching hospital), Kattankulathur, Tamil Nadu, India, from February 2021 to January 2022. A total of 150 neonates with hyperbilirubinaemia in the phototherapy range, American Academy of Paediatrics (AAP), were included in this study. Study subjects were divided into three groups of 50 neonates each to receive phototherapy using one of the three phototherapy devices, i.e., blue and white light, CFL, LED phototherapy groups. Data of serum bilirubin levels were recorded at the beginning and end of phototherapy. The number of babies who required exchange transfusion and other clinical side effects among the study groups was recorded. Descriptive statistics were reported as Mean±SD for continuous variables, frequencies (percentage) for categorical variables. The One-way Analysis of Variance (ANOVA) test was used to determine the statistically significant differences between the means of three independent groups.

Results: All the three type of phototherapy units generated statistically non significant mean flux (p-value=0.754). Mean difference (from the baseline bilirubin) at end of phototherapy for blue and white light group was 5.77±1.72 mg%, for CFL group was 5.48±1.32 mg%, and for LED group was 6.34±1.48 mg%. The difference was statistically significant in all three groups (p-value=<0.001). The reduction in serum bilirubin at the end of phototherapy was lesser in CFL group compared to blue and white light group and LED group.

Conclusion: Light-emitting diode and blue and white light phototherapy units are more effective than CFL phototherapy in treating neonatal hyperbilirubinaemia.

Keywords: Blue and white light phototherapy, Compact fluorescent lamp phototherapy devices, Efficacy, Light-emitting diode, Side effects

INTRODUCTION

Unconjugated hyperbilirubinaemia occurs as a result of increased bilirubin production from excessive lysis of Red Blood Cells (RBC) during the first week of neonatal life and also because of the inability of the neonatal liver to clear bilirubin rapidly enough from the blood. In India, various researchers report an overall neonatal jaundice rate ranging from 54.6-77%. About 4-8% of neonates develop pathological jaundice [1]. In a study by Dutta D et al., neonatal jaundice constituted 15.3% of Neonatal Intensive Care Unit (NICU) admissions [2]. Many of them suffer from unconjugated hyperbilirubinaemia.

Babies with jaundice need to be monitored closely, as higher serum bilirubin is potentially toxic to the central nervous system which can lead to bilirubin encephalopathy and subsequently kernicterus, with devastating permanent neurodevelopmental handicap [3]. Consequently, treatment should be expedited as soon as possible. Phototherapy is a widely used treatment modality for neonatal jaundice.

Halogen or compact fluorescent lamps are commonly used in conventional phototherapy. The advantages of LED phototherapy are their less power consumption, durability, compact size of the device and minimal heat production [4]. Researchers Gutta S et al., and Karagol BS et al., found that the total serum bilirubin levels decreased significantly when phototherapy was given using LED [5,6].

According to reports by Mohammadizadeh M et al., and Takci S et al., there is no significant difference between the LED and conventional phototherapy groups regarding serum bilirubin reduction [7,8]. Another study by Ngerncham S et al., concluded that special blue fluorescent tubes phototherapy is more effective than LED phototherapy in reducing serum bilirubin level [9]. In contrast, the Cochrane review in 2011 concluded that phototherapy with either LED or conventional light sources reduced serum total bilirubin levels equally [10].

Bilirubin molecules on exposure to phototherapy light, undergo photochemical reactions viz configurational isomerisation, structural isomerisation, and photo-oxidation to form nontoxic, excretable water-soluble isomers which can be excreted from the liver into the bile without undergoing conjugation or requiring special transport for their excretion.

Light-emitting diode and compact fluorescent lamp phototherapy units are the newer devices in the management of neonatal hyperbilirubinaemia. The advantages of LED phototherapy include portability, energy efficiency, less heat production and durability, but these are more expensive. Blue and white light phototherapy devices are more economical but generate more heat leading to hyperthermia and dehydration often.

Hence, this study was conducted in a tertiary care centre to compare the effects of these three phototherapy devices viz blue and white, CFL, LED on neonates having jaundice.

MATERIALS AND METHODS

This cross-sectional study was conducted in Department of Paediatrics at SRM Medical College Hospital and Research Centre (tertiary care teaching hospital), Kattankulathur, Tamil Nadu, India, from February 2021 to January 2022. This study was approved by the Institutional Ethical Committee prior to its commencement (SRM Medical College Hospital and Research Centre Ethics Clearance No: 2366/IEC/2021).

Inclusion criteria: Neonates with

a) Indirect hyperbilirubinaemia in phototherapy range requiring phototherapy as per AAP guidelines [11], and gestational age more than 35 weeks,

b) Birth weight more than 2000 grams.

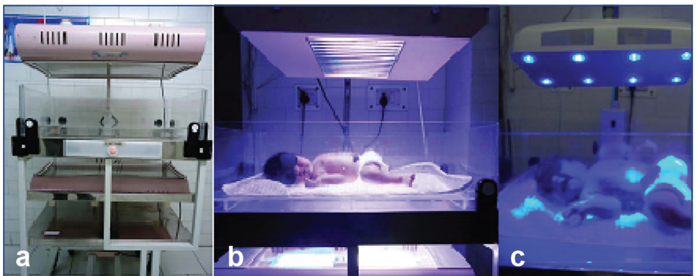
c) Exclusively breastfed and healthy were considered to be included in the study.

Exclusion criteria: Sick babies on intravenous fluids/medications like antibiotics, birth injuries (cephalhematoma) and babies with direct hyperbilirubinaemia , serum conjugated bilirubin level of more than 20% of total bilirubin were excluded from the study.

Sample size calculation: Power analysis for a one-way ANOVA fixer effect with three groups was conducted in G*Power to determine a sufficient sample size using an alpha of 0.05, a power of 0.80, and large effect size (f=0.40). Based on the aforementioned assumptions, the desired sample size is 40 per group. The total sample size was calculated as 150 including 20% attrition rate of 50 per group.

Study Procedure

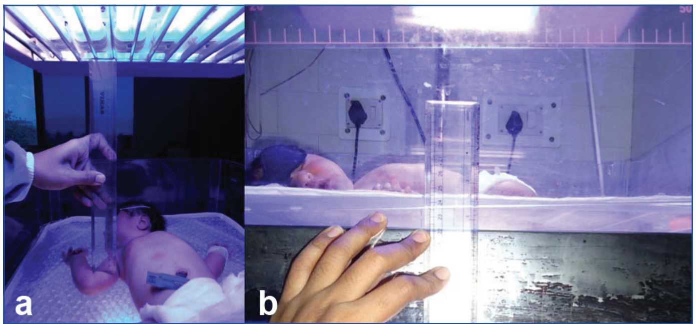
Total 150 neonates having jaundice in the phototherapy criteria were divided into three groups of 50 neonates each and were subjected to one of the phototherapy units viz. Blue and white light phototherapy (B&W), CFL phototherapy or LED [Table/Fig-1]. After obtaining informed consent from the parents, the newborns appearing icteric on clinical examination were subjected to estimation of baseline serum bilirubin levels. Relevant history and complete physical examination were recorded for all the neonates.



[Table/Fig-1]: a): Left picture showing blue and white light; b): Middle picture showing CFL; c): showing LED phototherapy unit.
(All three devices are manufactured by Phoenix medical equipment)

The irradiance of the blue and white light phototherapy unit was increased using aluminium foils as reflectors [Table/Fig-2]. The babies were positioned 30 cm from the top and bottom surfaces of all phototherapy units [Table/Fig-3].

[Table/Fig-2]: Blue and white light phototherapy unit with aluminium foil enhancing irradiance.



[Table/Fig-3]: a): Measurement of distance between the baby and upper; b): Lower surface of phototherapy unit.

The irradiance delivered in all three phototherapy devices was between 25-32 μW/cm^2/nm. The mean irradiance delivered in all three phototherapy devices was 27 μW/cm^2/nm which was closer to intensive phototherapy. The interrupted time during phototherapy like feeding time, blood sampling time, diaper change time etc were calculated and deducted, to get the actual duration of phototherapy in hours.

Serum bilirubin levels were checked at the initiation of phototherapy, at 24 hours, and end of phototherapy using the 2,5-Dichlorophenyldiazonium tetrafuoroborate (DPD)/Jendrassik-Groff method. Non invasive Transcutaneous Bilirubin (TcB) was carried out at 24 hours after initiating phototherapy for monitoring the effect of phototherapy. Non-invasive TcB measurement was done over the forehead and sternum and the average value was recorded [Table/Fig-4].

[Table/Fig-4]: Non-Invasive Transcutaneous Bilirubin (TcB) measurement over forehead (Top image) and Sternum (Bottom image).

Data Collection

Baseline characteristics of study groups (birth weight, gestational age, gender, haemoglobin and age (in hours of life) at the initiation of phototherapy, and mean flux delivered were recorded. Serum bilirubin levels were measured in the laboratory at the start and completion of phototherapy. Because the results of non invasive TcB cannot be trusted after the skin surface has been exposed to irradiance for a few hours, a laboratory serum bilirubin level was measured at the end of phototherapy. A flux meter was used to measure irradiance [Table/Fig-5].

[Table/Fig-5]: Flux meter reading taken under a normal tube light (top picture) and phototherapy light (bottom).

A five point measurement of flux was taken from all four corners and the centre of the phototherapy unit bed (where the baby was positioned for phototherapy) and the average of these five readings was taken for calculating flux. In accordance with the AAP chart, the decision to stop phototherapy was based on a reduction in serum bilirubin to below the phototherapy range [4].

Outcome measures: Efficacy of the phototherapy was judged by the following outcome measures:

Primary outcome: Need for exchange transfusion

Secondary outcomes: Mean serum bilirubin value at the point of decision to stop/end of phototherapy, and side effect profile.

STATISTICAL ANALYSIS

The obtained data was entered in Microsoft excel. Statistical analysis was done using Statistical Package for the Social Sciences (SPSS) software version 19.0. One-way Analysis of Variance (ANOVA) was used for the comparison of mean total serum bilirubin between the groups for variables such as birth weight, gestational age, haemoglobin, age in hours at the start of phototherapy. Qualitative variables such as gender and adverse events were analysed using the Chi-square test. Significance was taken as p-value <0.05.

RESULTS

At the start of phototherapy, there was no significant difference between the three groups of neonates in terms of birth weight, gestational age, gender distribution, or haemoglobin (one-way ANOVA, p-value >0.05) [Table/Fig-6].

The three groups did not differ significantly in age criteria (hours of life) at the start of phototherapy (one-way ANOVA, p-value >0.05). The duration of phototherapy was similarly not significantly different across the groups (one-way ANOVA, p-value >0.05). There was no statistical difference between the mean fluxes delivered between the groups.

When the mean bilirubin values of the three groups were compared at the start of phototherapy, no significant differences were found. This holds true for Transcutaneous bilirubinometer (TcB) measurement as well. The mean total bilirubin levels, recorded after 24 hours, did not differ significantly between the three groups (one-way ANOVA, p-value >0.05) [Table/Fig-7].

Mean difference from the baseline bilirubin at end of phototherapy Laboratory value (mg%) (Mean±SD) for blue and white light group was 5.77±1.72, for CFL group was 5.48±1.32, and for LED group was 6.34±1.48. The difference was statistically significant in all three groups [Table/Fig-8]. The reduction in serum bilirubin at the end of phototherapy was greater in blue and white and LED group when compared to CFL group.

None of the babies in the three groups required exchange transfusion and all the babies were successfully treated with one of these devices and discharged [Table/Fig-7].

Variables	Blue and white light (Mean±SD)	Compact fluorescent lamp (Mean±SD)	Light-emitting diode (Mean±SD)	F-value	p-value
Birth weight (grams)	2886.70±218.76	2871.30±206.72	2892.78±215.53	0.134	0.875
Gestational age (Weeks)	38.24±0.87	38.28±0.97	38.02±0.98	1.107	0.333
Gender-Male (%)	24 (48%)	23 (46%)	29 (58%)	1.654	0.437
Rh incompatibility	0.04±0.20	0.04±0.20	0.04±0.20	0.00	1.000
ABO incompatibility	0.08±0.27	0.08±0.27	0.08±0.27	0.00	1.000
Haemoglobin at start of phototherapy (gms%)	16.30±1.02	16.57±1.14	16.77±1.23	2.215	0.113
Age at start of phototherapy (hours)	69.82±12.61	69.58±12.23	68.90±14.17	0.067	0.935
Duration of phototherapy (in hours)	41.22±13.42	41.46±14.02	41.62±13.12	0.011	0.989
Mean flux delivered (μW/cm²/nm)	26.96±4.27	27.22±4.04	27.74±7.01	0.283	0.754

[Table/Fig-6]: Summary statistics of patient characteristics and comparison of groups.
p-value <0.05 was considered as significant

Variables	Blue and white light (Mean±SD)	Compact fluorescent lamp (Mean±SD)	Light-emitting diode (Mean±SD)	F-value	p-value
Bilirubin at start of therapy: TcB (mg%)	18.35±0.98	18.65±1.22	18.48±1.12	0.893	0.411
Bilirubin at start of therapy: Laboratory value (mg%)	18.16±1.57	18.29±1.25	18.53±1.16	0.997	0.371
Bilirubin at 24 hrs of therapy: TcB (mg%)	15.79±0.37	16.05±0.69	15.91±0.58	2.825	0.063
Bilirubin at the end of phototherapy: Lab (mg%)	12.39±0.71	12.78±0.31	12.19±0.89	9.688	0.0001

[Table/Fig-7]: Summary statistics of bilirubin levels among study groups.
TcB: Transcutaneous bilirubinometer; No Exchange Transfusions required by any group; p-value <0.05 was considered as significant

Group	Bilirubin (mg%) at beginning of phototherapy	Bilirubin (mg%) at end of phototherapy	Mean±SD	t-value	p-value
Blue and white light	18.16±1.57	12.39±0.71	5.77±1.72	23.59	<0.001
Compact fluorescent lamp	18.29±1.25	12.78±0.31	5.48±1.32	29.11	<0.001
Light-emitting diode	18.53±1.16	12.19±0.89	6.34±1.48	30.25	<0.001

[Table/Fig-8]: Comparison of bilirubin laboratory (mg%) among three groups at the beginning and at the end of phototherapy.
p-value <0.05 was considered as significant

All three phototherapy units generated statistically negligible mean flux (p-value >0.05). Overall, the side effects like rashes and loose stools noted among all the three groups were minor and transient and did not necessitate stopping of therapy. Out of six babies who developed mild dehydration, four were in blue and white light group and one each in CFL and LED group [Table/Fig-9].

Side effects	Blue and white light	Compact fluorescent lamp	Light-emitting diode	Chi-square	p-value
Dehydration and weight loss	4	1	1	1.948	0.745
Rashes	1	1	2		
Loose stools	2	1	2		

[Table/Fig-9]: Side effect comparison among different phototherapy units.

They did not require any intervention, as it was mild and was managed with frequent timely feeding by the mothers.

DISCUSSION

In routine clinical practice, a variety of phototherapy light sources are employed, with different manufacturers suggesting that newer lights, such as CFLs and LEDs, have a higher efficacy [12].

For newborns with substantial hyperbilirubinaemia, the most effective light source with the fewest side effects would be preferred if the phototherapy device availability is not an issue. In light of this, the current study was designed to compare the efficacy and side effects of various phototherapy units, Viz., blue and white, CFL and LED. The mean irradiance delivered by all three phototherapy units was 27 μW/cm²/nm which was closer to the intensive phototherapy range (Irradiance level for intensive phototherapy is >30 μW/cm²/nm as per AAP) [11]. The American Academy of Paediatrics currently recommends special blue fluorescent lamps or LED lights as these are effective in various clinical studies [11]. Chang, et al., found that using a high-intensity LED device was far more effective than using traditional phototherapy [12]. However, LED devices were not shown to be more effective than other modalities of phototherapy in a Cochrane review published in 2011 that compared six trials [10]. Another study by Jain PK et al., showed LED phototherapy is superior to CFL phototherapy in the management of neonatal hyperbilirubinaemia in terms of efficacy and side effects. The irradiance of LED group was 49 μW/cm²/nm and that of CFL group was 40 μW/cm²/nm [13]. In the present study, there was no difference in terms of efficacy between blue and white light and LED groups which is similar to a Cochrane review published by Kumar P et al., [10].

Adhikari KM et al., compared the efficacy of three different phototherapy units (blue and white, CFL and LED phototherapy devices) with a mean irradiance of 45-55 μW/cm²/nm. They found that the mean total serum bilirubin level at the end of phototherapy did not show any statistical significance between these three groups [14].

In the present study, with a mean irradiance of 27 μW/cm²/nm, it was found that LED phototherapy and blue and white light phototherapy were more effective than CFL phototherapy.

Gutta S et al., compared conventional blue and white light phototherapy with LED phototherapy. In his study, 166 neonates [5], (83 in each mode of phototherapy) were placed 30-40 cm away from the light source with an irradiance of 8-12 μW/cm²/nm for blue and white and 30-40 μW/cm²/nm for LED phototherapy unit. The study concluded that LED phototherapy was more effective in decreasing total serum bilirubin than blue and white light phototherapy. In the current study, the baby was positioned at 30 cm from the light source and irradiance of blue and white was enhanced with aluminium foils to achieve a spectral irradiance closer to Intensive phototherapy range similar to LED phototherapy. Higher irradiance of LED phototherapy group could have contributed to the superiority of this device in the above study.

Efficacy of LED phototherapy and conventional phototherapy in decreasing serum bilirubin was not significantly different between the groups according to reports by Mohammadizadeh M et al., Takcı S et al., which is similar to the index study [7,8]. As per a study by Ngerncham S et al., special blue fluorescent tubes phototherapy, is more effective than LED phototherapy in reducing serum bilirubin level [9]. In this study, the irradiance of special blue fluorescent tubes phototherapy was twice higher than that of LED phototherapy.

In present study, the reduction in serum bilirubin was lesser in CFL phototherapy group when compared to the B&W light phototherapy group and LED group. In all three study groups, none of them required Exchange transfusion. The adverse effects noted in the study subjects were dehydration, weight loss, loose stools and rashes, which were comparable among the groups. In a study by Jain PK et al., fever was the most common adverse effect due to phototherapy [13]. In the present study, dehydration and rashes were the predominant adverse effect, which is similar to a study by Adhikari KM et al., [14]. All rashes were self-limiting and disappeared on their own. Periodic reinforcement to mothers by staff about the necessity of regular temperature monitoring and timely feeding of babies while on phototherapy reduced the incidence of both hyperthermia and dehydration. Since, the study excluded babies with birth weight <2000 gm and sick babies, it was possible to ensure exclusive breastfeeding of all the neonates in the study group.

Limitation(s)

The mean irradiance delivered in all the phototherapy devices was less than the intensive phototherapy range, and babies were positioned 30 cm away from the phototherapy light source. Irradiance could have been increased by positioning the babies even closer to the light source. Serial measurements of the rate of fall of serum bilirubin levels could have strengthened the comparison of these three different phototherapy devices.

CONCLUSION(S)

Light-emitting diode and blue and white phototherapy units are more effective than compact fluorescent lamp phototherapy in treating neonatal hyperbilirubinaemia. If effective irradiance, adequate feeding, and constant monitoring were maintained, all three phototherapy devices could treat hyperbilirubinaemia effectively and safely. Larger multicentric trials are required for establishing the superiority of blue and white light or LED phototherapy for effectively treating neonatal hyperbilirubinaemia.

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