A Novel Design of Low Cost LED Photo Therapy Equipment

Sri Logeshwaran R1, Siva Kumar P3, Kuldeep S1, Pravin Kumar S2,

1Bachelor of Engineering, 2Associate Professor - Department of Biomedical Engineering,
1,2 Sri Sivasubramaniya Nadar College of Engineering, Tamil Nadu, India
3Master of Science, Arizona State University, U.S.A.

ABSTRACT

The photo therapy in the medical terminology has been an effective treatment methodology to treat certain illnesses with the exposure of light. Generally in the neonatal care, photo therapy is mainly used for treatment of neonatal jaundice in the new born babies, cancer, etc. Also photo therapy has also been used for wound healing, to promote relaxation, improve fertility and simulate hair growth. Several photo therapy methods have been in existence for treatment of such illness. The existing photo therapy device to cure jaundice in neonates uses fluorescent lamp, halogen lamp, LED’s as a direct spot light which is kept 35cm away from the patient on top of the bassinets, incubators and warmers. The need for a new technology arises to fulfill certain drawbacks in the current technology which includes warming the ambient air around baby which leads to water loss in neonates; exposure of naked eye to the treatment; uneven distribution of intensity; more space requirement in NICU and high cost which is prevailing in the market for 1500$. In addition, the present equipment uses a power of minimum 60 Watts which doesn’t suit the remote places of developing countries as they don’t enjoy uninterrupted power and doesn’t act portable. The basic idea behind this project is to develop a low power LED based phototherapy unit to provide uniform light distribution intensity over a specified area of interest; pragmatically very low heat dissipation from the unit which accounts for no water loss from the baby; no need for eye goggles to protect the eyes; solar powered; rechargeable; portable and an effective treatment with a low cost technology.

Using a 470nm nanometer wavelength of Blue band light, this device will help to reduce the bilirubin content in the neonates affected with jaundice which is prevailing in every 50-60% of new born babies. The photo therapy treatment depends on the intensity of light and its surface area of exposure. A transparent sheet of dimensions with thickness around 1.5cm, length 75cm and width 50cm with 10 high power LED’s Shall be 450-470nm light at the sides is under development

Keywords: Bilirubin, Jaundice, LED, Neonatal, NICU, Phototherapy.

1. INTRODUCTION

Bilirubin is a yellow substance that the body creates when it replaces old red blood cells. The liver helps break down the substance so it can be removed from the body in the stool. Newborn jaundice is when a baby has high levels of bilirubin in the blood. High levels of bilirubin make the baby's skin and whites of the eyes look yellow. This is called jaundice – (Newyork Times Health guide). It is normal for a baby's bilirubin level to be a bit higher after birth. When the baby is growing in the mother's womb, the placenta removes bilirubin from the baby's body. The placenta is the organ that grows during pregnancy to feed the baby. After birth, the baby's liver starts doing this job. This can take a while. Most newborns have some yellowing of the skin, or jaundice. This is called
"physiological jaundice." It is harmless, and usually is worst when the baby is 2 - 4 days old. It goes away within 2 weeks and doesn't usually cause a problem.

Two types of jaundice may occur in newborns that are breast fed. Both types are usually harmless.

**Type 1:** Breastfeeding jaundice is seen in breastfed babies during the first week of life, especially in babies who do not nurse well or if the mother's milk is slow to come in.

**Type 2:** Breast milk jaundice may appear in some healthy, breastfed babies after day 7 of life. It usually peaks during weeks 2 and 3. It may last at low levels for a month or more. It may be due to how substances in the breast milk affect how bilirubin breaks down in the liver. Breast milk jaundice is different than breastfeeding jaundice. [1]

Severe newborn jaundice may occur if your baby has a condition that increases the number of red blood cells that need to be replaced in the body, such as: Abnormal blood cell shapes, Blood type mismatch between the mother and the baby, Bleeding underneath the scalp (cephalohematoma) caused by a difficult delivery, Higher levels of red blood cells, which is more common in small-for-gestational-age babies and some twins Infection and Lack (deficiency) of certain important proteins called enzymes

Many studies have scientifically proved that the 450-475nm wavelength LED can be used for the Bilirubin absorption which is evident from the graph. Many Photo-therapy devices has been manufactured with fluorescent lamp, halogen lamp, LED's as a direct spot light 2which is kept 35cm away from the patient over the incubators or warmers [2,3].

![Fig 1. Wavelength vs. Absorption Graph](Source: Natus Medical Incorporation NeoBlue phototherapy Device)

After discovery of the incandescent bulb, LEDs is the biggest leap in lighting technology. An LED (Light Emitting Diode) converts electrical energy into light, with heat as an unwanted and highly problematic by-product. The heart of an LED is called ‘Die’. A Die is composed of several materials specially selected for certain physical properties and exhibiting the so-called semiconductor effect. To prevent overheating, the die for a high-power LED is secured on a heat sink that often doubles as the case. The die has wires attached to it for the electrical connection [4].

![Fig 2. LED Principle Arrangement.](Source: Natus Medical Incorporation NeoBlue phototherapy Device)
Because they produce no infrared energy, the beam of light from an LED source is cool. However, waste heat is produced within the LED itself during the conversion of electricity into light. This waste heat must be properly removed from the lighting system to maximize fixture performance and to avoid damage to the LEDs. In well-designed LED lighting fixtures, heat removal is accomplished through carefully designed and engineered heat sinks that draw heat away from the LEDs and dissipate it into the air surrounding the fixture housing [5]. Considering these parameters which are essential while designing results in a better heat distribution channel design to minimize hot spots.

From the Intensity level of the different colors of the LED it’s evident that Blue LED lies in the intensity range of 425-475nm so Blue LED are chosen as the source of light for the therapy [5].

<table>
<thead>
<tr>
<th>LED Color</th>
<th>Standard Brightness</th>
<th>High Brightness</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Chip Material</td>
<td>Ipk (NM)</td>
</tr>
<tr>
<td>Red</td>
<td>GaAsP/GaP</td>
<td>635</td>
</tr>
<tr>
<td>Orange</td>
<td>GaAsP/GaP</td>
<td>605</td>
</tr>
<tr>
<td>Amber</td>
<td>GaAsP/GaP</td>
<td>583</td>
</tr>
<tr>
<td>Yellow</td>
<td>GaP</td>
<td>570</td>
</tr>
<tr>
<td>Green</td>
<td>GaP</td>
<td>565</td>
</tr>
<tr>
<td>Turquoise</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td>Blue</td>
<td>--</td>
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</tr>
</tbody>
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Fig 4. (a) Composition of LED wide ranges (b) Intensity Color Distribution chart

According to a bilirubin chart in new born babies, the normal values that have been highlighted are:

**Premature Babies**
- Less than 24 hours: Below 8.0 mg/ dl (below 137 mmol/ l)
- Less than 48 hours: Below 12.0 mg/ dl (below 205 mmol/ l)
- Aged between 3 and 5 days: Below 15.0 mg/ dl (below 256 mmol/ l)
- Aged 7 days and older: Below 15.0 mg/ dl (below 256 mmol/ l)

**Full Term Babies**
- Less than 24 hours: Below 6.0 mg/ dl (below 103 mmol/ l)
- Less than 48 hours: Below 10.0 mg/ dl (below 170 mmol/ l)
- Aged between 3 and 5 days: Below 12.0 mg/ dl (below 205 mmol/ l)
- Aged 7 days and older: Below 10.0 mg/ dl (below 170 mmol/ l)

With full term babies, if the bilirubin levels are slightly higher than the normal values listed in the bilirubin chart for neonates, then treatment may not even be required. However, all instances of high levels of bilirubin in a child should be closely monitored by a doctor [6].

2. **METHODOLOGY**

From the detailed research and study of phototherapy & it’s present day drawbacks, the new idea with a nouvelle concept was implemented. A transparent sheet of thickness around 1.5cm, length 75cm and width 50cm was chosen. Using the property of light, an obstruction to its pathway was created along with total internal reflection makes the sheet glow at a specific area of interest.
standard blue color LED of 450nm has been chosen as the source of illumination. Unlike conventional medical equipment's, it consumes less power, less heat dissipation, requires no eye goggles, no water loss in babies, portable and solar powered battery operated with a uniform heat distribution.

**Fig. 5 Transparent Sheet**

The LED’s are placed at the sides of the sheets as shown in fig 6. It is made sure that light don’t interfere from the sides which results in bright spots at certain areas of the sheet and the same is accomplished by LED placements. Unlike other instruments, this does not dissipate heat which avoids dehydration in neonates. The entire prototype works with 5V, consuming less than an Ampere which is backed up by a battery with a solar charging circuit.

**Fig 6. LED Arrangement**

The LEDs are generally bandage embodiments that target a small area of the tissue. Using a 470nm nanometer wavelength of Blue band light, this device will help to reduce the bilirubin content in the neonates affected with jaundice. The photo therapy treatment depends on the intensity of light and the surface area of light exposure. The device is provided with a battery backup and also with a Processor and LCD Display. The entire circuitry of the instrument is provided with the block diagram.

**Fig 7. Setup Arrangement**

3. **RESULTS & DISCUSSIONS**

A prototype is successfully designed and the LEDs are arranged in parallel zigzag patterns in order to utilize the spreading beam of light into a uniform distribution of light intensity. The entire system works with 5 Volts of power and an additional battery is provided along with the prototype which will backup for more than 12 hours of continuous usage. The distribution of the light over the transparent plate is almost uniform as shown in the figure 8.

Two mainly used types of phototherapy devices: the conventional phototherapy light which has been used for over 40 years and the LED phototherapy device which is replacing the conventional models. The conventional phototherapy device uses tungsten halogen bulb, a metal halide gas discharge tube, long or compact (or folded) fluorescent lamps, and most recently, light emitting diodes (LEDs). The light source is positioned above or below the baby and the irradiance is dependent on the distance between the baby and the lights.
Much of the existing Photo therapy units use fluorescent lamps or array of LEDs as the source of light, but the major drawback of all is that, they dissipate heat to the ambient air or the contacting skin which in turn results in water loss in the new born baby. ‘NeoBluecozy’ photo therapy device is one among the device under study which uses a multiple array of LED’s under a transparent sheet [7]. From our observation, the degree of freedom provided by the device to the baby is restricted, high cost, intensity focused on the center, high power consumption.

Maisels describes a system in which special blue lights were positioned to within 14 cm of the mattress. He adds a cautionary note: “halogen phototherapy lamps cannot be positioned closer to the infant without incurring the risk of a burn” [8]. Close attention to the operating instructions is very important [9]. In its simplest form a conventional photo therapy device has a lamp head mounted on an adjustable, mobile stand. The lamp may then be positioned at a distance from the baby’s skin. The manufacturer usually specifies a minimum distance at which a device may be used and this can vary from 25cm to 50cm, which is usually takes much time to observe and also heat is produced due to projection of lights for a longer period, so this method is not encouraged much.

Shatalov, M & et al has devised the phototherapy apparatus by arranging 40 LEDs parallely in form of arrays and projected by facing the baby’s body. This device is embedded with incubators where these LED arranged panel is kept over the incubator and both incubator and phototherapy unit has to function. The major drawback is the heaters in the incubator will cause water loss, and the LED which is kept in the distance of 35m away from the baby will take longer time to maintain the bilirubin level [10].

Phototherapy devices from the industries like Phoenix & Lumitex, the design utilizes of LED array with the intensity level between 450-475nm. These LEDs are arranges in a fashion which are projected over the baby’s body parallely, where these can be utilized with the incubator or warmers with a distance away from the equipment (Phoenix infant Jaundice care & Lumitex Bilisoft). They still suffer the heat dissipation, water loss, high power and high cost.

Stephanie D.P. & Wentworth et. al., describes the relationship is related to the inverse square law, that is, the intensity of light decreases as the square of the distance [11]. The irradiance at a distance of two meters will only be a quarter of the irradiance at one meter from a light source. However, the relationship in reality is more complex than this and the decrease in irradiance with distance tends to be less because the light is rarely a point source [12]. It’s clear that the closer the lights can be positioned to the infant the higher the irradiance, but care must be taken with the safety of such an arrangement to prevent overheating the neonate and also to ensure that as much of the infant’s skin is illuminated as possible.

The GE healthcare based phototherapy unit is fiber optics based technology for treatment of indirect hyperbilirubinemia in new borns. Its increased surface area, high spectral irradiance, and long lasting blue narrow-band LED light, which utilizes much power and cost effective one (GE LED Phototherapy device). These type of devices use a standard light source, usually a quartz halogen bulb. Quartz halogen bulbs have not been noted to reduce in intensity with age but they are quite fragile, especially when hot, and care must be taken to prolong their lifetime [13, 14]. The disadvantage of the device is that fiber optics cannot expose a larger surface area over skin and also the cost of maintenance is higher.
4. CONCLUSION

This product can be embedded into the neonate incubator or warmer which will result in even distribution of light exposure with very low heat dissipation. It is a battery operated circuit supported by both conventional and solar charging which will be of utmost use in remote areas of the developing world. This simple product has the potential to replace the sophisticated medical equipment which are conventionally prevalent in the urban hospitals all over the world and also would save a lot of money, energy and provide an efficient treatment reducing water loss in the baby thereby reducing weight loss. Future development of ultra-portable; even distribution; micro energy harvesting support device is under progress.

REFERENCE


