

AUTOMATED PHOTOTHERAPY VEST

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Abstract

Phototherapy is the most commonly used therapeutic intervention for the treatment of hyperbilirubinemia (jaundice). Fiberoptic, fluorescent tubes, halogen bulb and also LEDs are among regular light sources used for phototherapy. Phototherapy treatments using fluorescence light which is usually used in hospitals require continuous uninterrupted treatment period and need infants to be uncovered and only wear eye patches. These conditions are not preferable for infants as they tend to get cold easily and feel uncomfortable. It is also not encouraging for breastfeeding mothers as the treatment needs to be continuous. The rapid development of high intensity light-emitting diodes (LEDs) makes feasible the use of LEDs, among other light sources for use in the design of a garment phototherapy device. The paper describes the design of a phototherapy vest for infants, using ultraviolet (UV) LEDs and Arduino microcontroller for use in reducing bilirubin level in infants with jaundice. The garment phototherapy device is comfortable to wear and infants are no longer required to wear eye patches. The proposed device is portable, uses a small power supply and easy to be operated anywhere.

Introduction

Hyperbilirubinemia or also known as jaundice is a disease that is common in newborn infants. It is the yellowing of the skin and other tissues due to the increase of bilirubin level in an infant's body. Almost 60% to 70% of infants at the age of 35 weeks to 38 weeks, have a greater risk of

encountering jaundice which can either happen in premature or full-term infants [1]. Jaundice can be divided into physiologic and pathologic. Physiologic is compassionate and common in normal infant, whereas pathologic jaundice despite bile pigments in the brain stem, causing brain damage known as kernicterus. Jaundice happens due to several factors, which include blood incompatibility between the mother and infant (both have different blood rhesus), lack of enzyme which causes unstable red blood cells when exposed to certain substances, virus infections in infant such as rubella, herpes simplex and also syphilis, and immature liver condition during breakdown of red blood cells [2]. All of these factors may lead to increase in bilirubin level inside an infant's body and it can cause death if not treated immediately.

Conventionally, jaundice is treated by exposing the infant to sunlight, preferably in the early morning or late evening. It is important not to expose the infant directly to sunlight as it can cause burns to the infant's sensitive skin. The infant can be placed in a room that receives sufficient sunlight and exposed for thirty (30) minutes. It is essential to get the infant to be comfortable during the treatment. The treatment is repeated several times in a day which usually should be able to decrease the infant's bilirubin level within a week.

Nowadays, the most common medical treatment to cure jaundice is through phototherapy. Infants will be exposed under blue light for a certain period of time until their bilirubin level decreases to a level that is safe for the infant. By exposing infants under UV light, bilirubin will be discrete from

the infants' bodies through their feces and urine which changes the bilirubin to its break down compound. Lumirubin and photobilirubin are compounds produced from bilirubin by exposing it to a certain wavelength of light as both are isomers of bilirubin that have been rearranged from the same atoms. In phototherapy, when light penetrates the skin, bilirubin will be converted into its isomers (photobilirubin and lumirubin) and removed from the body without the involvement of the liver [3].

Over the years, there have been significant improvements in the medical technology field, similarly in phototherapy treatments. Hospitals have been equipped with various types of phototherapy devices to treat patients with jaundice, particularly newborns. The use of these devices are proven to be able to treat jaundice more effectively while reducing the duration of treatment with less risk to the infants [4]. The light source for these phototherapy devices ranges from fluorescent bulbs, halogen bulbs, and also fiberoptics [5]. The latest phototherapy devices now use the technology of light emitting diode (LED) which has proven to be able to reduce bilirubin level faster compared to other phototherapy device [4].

Materials & Method

There are several factors that need to be considered to determine the LEDs' arrangement. These include the effective light field, light wavelength and also maximum power dissipation of the UV LEDs. The SI unit used is mW/cm^2 . Below are the calculations that were used to determine the position of the LEDs on the garment and the distance between each LED.

$$UV\ LED\ Wavelength = 385\ nm - 395\ nm$$

$$Max\ Power\ Dissipation = 80\ mW$$

$$Effective\ Light\ Field = (Length \times Width)\ of\ light\ exposure\ area$$

$$= 2\ cm \times 2\ cm$$

$$= 4\ cm^2$$

$$Irradiance = \frac{\left(\frac{Max\ Power\ Dissipation}{Effective\ light\ field}\right)}{Peak\ Wavelength}$$

$$= \frac{\left(\frac{80\ mW}{4\ cm^2}\right)}{390\ nm}$$

$$= 51.28\ \mu W / cm^2 / nm$$

The calculated irradiance value obtained is higher than the minimum irradiance required by The America Academy of Paediatrics (AAP) to treat jaundice. Referring to the AAP guidelines, as shown in Figure 5, intensive phototherapy is defined as the use of blue light delivered at $30\mu W/cm^2/nm$ or higher to the greatest exposed body surface area (BSA) as possible [2].

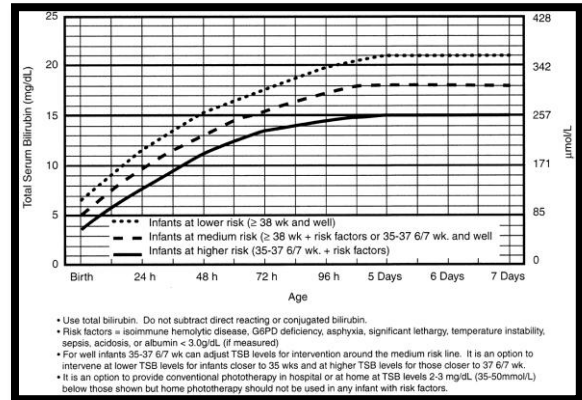
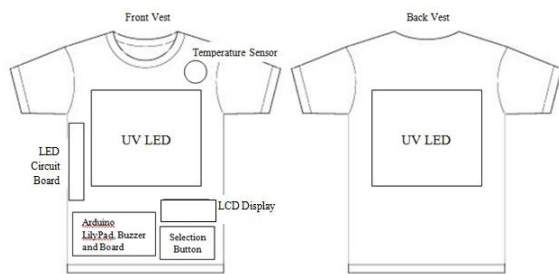


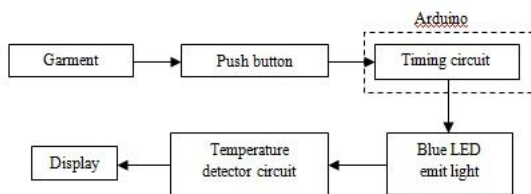
Figure 5: AAP Guideline for neonatal jaundice

Figure 6 illustrates the component layout and block diagram of the automatic phototherapy vest. The system is controlled by the Arduino Uno microcontroller, an open source electronics prototyping platform which is commonly used in designing interactive devices. All UV LEDs are sewn on the garment using conductive threads which are able to carry current for power and signal. The push button is used to set the duration of treatment which is only enabled when the infant's body temperature

is in the normal range. The timing circuit and the UV LEDs will be switched on once the period selection is set and switched off depending on the duration chosen. The device will automatically turn off and trigger the buzzer once the treatment period is complete. The temperature detector sensor continuously measures the infant's body temperature throughout the treatment period. All temperature readings and set time for the treatment will be displayed on the LCD.



(a) Component layout



(b) Block diagram

Figure 6: Automatic Phototherapy Vest

The design of the APV consists of two (2) main parts, the hardware part and software part.

Software

- The Arduino software (using C/C++ programming language) is used to program the Arduino Uno microcontroller, which acts as a brain for the system.
- The temperature output from the LilyPad Arduino temperature sensor is used to monitor infant's body temperature by comparing the measured temperature

with the set temperature (temperature for infant under normal condition = 36-37 °Celsius).

- The program also controls the ON/OFF switching duration of the UV LEDs and triggers the buzzer once treatment is complete.

Hardware

The Arduino Uno microcontroller board used in the APV is based on the ATmega328 which has 14 digital input/output pins. The component layout of the circuit designed for the APV consists of five (5) major parts which includes the:

- **Temperature Sensor Circuit**
The LM35 sensor is used to detect the infant's temperature level with a scale factor of 10mV/°C.
- **Liquid Crystal Display (LCD)**
The LCD displays the current infant's body temperature level which is received from the LilyPad Arduino temperature sensor.
- **Option Push Buttons**
The APV consists of three push buttons which includes the + (increase duration), - (decrease duration) and START (start treatment) button. These push buttons are used to set the treatment duration and also to start the treatment.
- **UV LEDs**
This is the main part of the device. The UV LEDs will emit UV light which will help to reduce the bilirubin level in the infant's body.
- **Buzzer**
The buzzer will trigger when the treatment is complete to alert guardian to attend to their babies.

Fig. 4 show the flow chart for this device, it explain how the Arduino software control the whole process in this device.

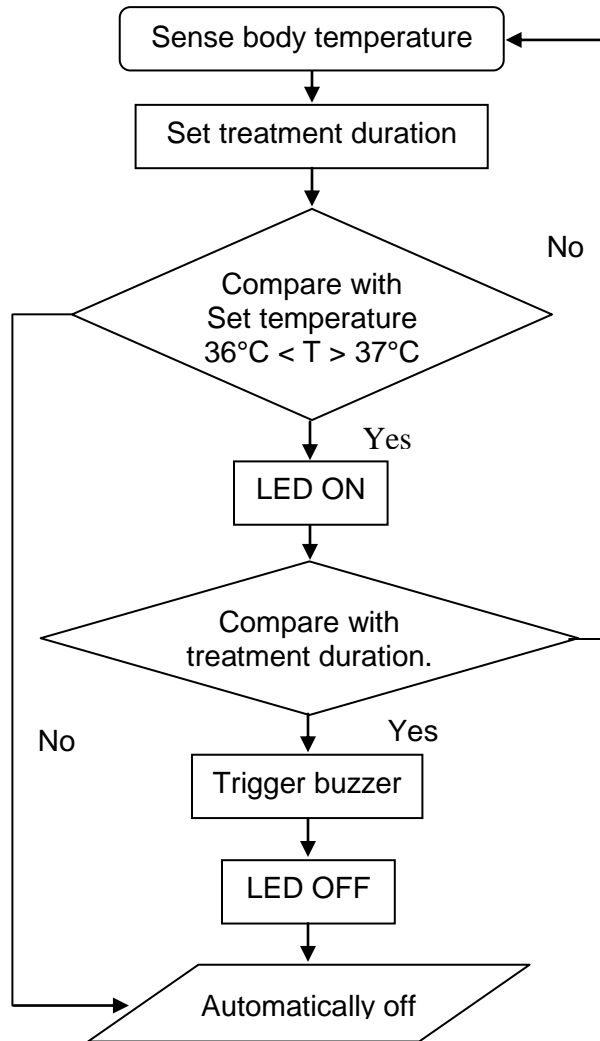


Fig. 4 Flow chart for APV

Results and Discussion

The controller (Arduino Uno) is able to control the switching of the UV LEDs. Each UV LED of the vest is able to emit $51.28 \mu\text{W}/\text{cm}^2/\text{nm}$ (effective light field for each LED is 4cm^2).

Figure 7 illustrates the device when it is in the switched off set up. When the APV is on it will greet the user with a welcome note

(Figure 9 (a)) and display the current infant's body temperature (Figure 9 (b)). The device will only enable user to set the duration of treatment if the detected infant's body temperature is in the range of the set temperature which is between 36°C - 37°C . To start the treatment, a user needs to choose the appropriate duration of treatment (Figure 9 (c)). Once the duration is set, the user needs to press the ON push button and the treatment will start automatically. All the UV LEDs will be switched on for the desired duration, as shown in Figure 8 and Figure 9(d). The temperature sensor will measure the infants' body temperature in every 1 second and will be displayed on the LCD. Once the treatment is complete, the buzzer will trigger to alarm the user and a complete notification message will be displayed on the LCD (Figure 9 (f)).

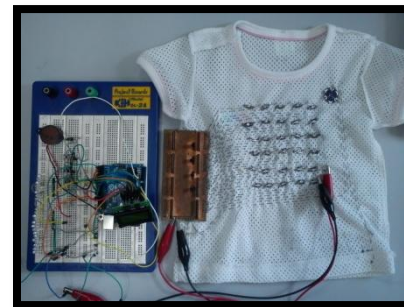


Figure 7: APV Full Set Up (LED switched off)

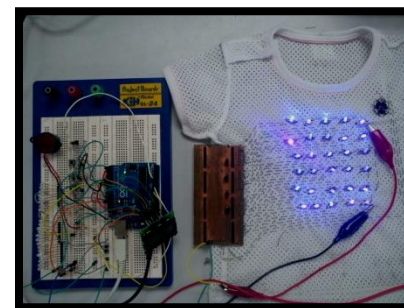


Figure 8: APV Full Set Up (Treatment on going, LED switched on)

Throughout the operation, user will be notified with a welcoming note, current infant's temperature, duration of treatment, complete treatment message and

notification if the infant's body temperatures exceeds the set temperature (Figure 4.8 (e)). Figure 4.8 illustrates the operation flow of the APV.

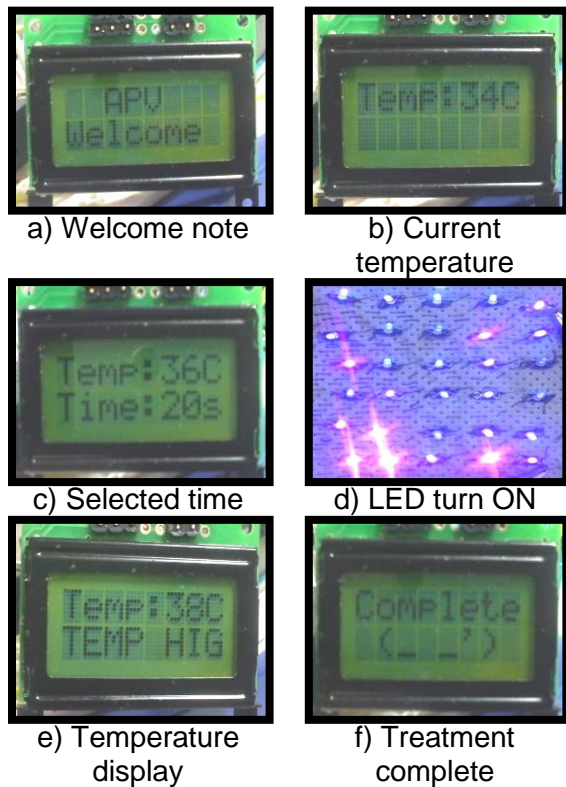


Figure 9: Complete operational flow of APV

7. Conclusion

The Automated Phototherapy Vest (APV) is designed to help in reducing infants' bilirubin level by exposing infants under the UV LED lights. The emitting UV LEDs from the phototherapy vest is able to emit the desired power which will help in reducing bilirubin level in an infants' body. The device is also able to monitor the infants' body temperature and automatically turns OFF when it detects that the temperature exceeds the limit temperature set in the device. The required power supply is small and the vest is easy to wear and comfortable to be operated at the hospital or even at home. The battery for this device can be easily replaced and it only requires a

low cost to the user. By using the APV, mothers no longer have to leave their babies at the paediatric wards and they are able to monitor their own baby's condition. Mothers can also breastfeed even during the treatment. The device will automatically turn OFF once treatment is complete and this prevents, the infants from getting an over exposure of the UV light even when the user/guardian is unaware of it. The buzzer will also acts as an alarm to remind the user/guardian that the treatment period has end and for them to attend to their babies.

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