Design and Construction of a Compact Model of Median Cubital Vein Transilluminator

T. Kaewgun, *P. Anupongongarch, K. Roongprasert
Faculty of Biomedical Engineering, Rangsit University, Pathumthani Thailand 12000
*preya.a@rsu.ac.th

Abstract — The objective of this research was to design and construction of a compact model of median cubital vein transilluminator to convenient for using and seeing vein more clearly in intravenous injection. This research has adopted the principle of the light absorption of the vein and the principle of electronics. The designed and constructed of the project was composed of 2 main parts: 1) The power supply 9 volt battery and 550 mAh and 2) The light source was composed of 660 nanometer wavelength of light emitting diode, LED driver circuit and IC LM 555 for adjusting the brightness of the light source. The results of functional test found that the compact model of median cubital vein transilluminator can be adjusted the brightness of the light source in the range of 1200 - 3500 lux and used to examine the vein easier and clearer than the conventional method. The user satisfaction testing result showed that the average satisfaction was 4.22 of 5 points.

Index Terms — Median Cubital Vein, Transillumination Device

INTRODUCTION

Nowadays, checking up body on regular basis is quite common as people want to stay healthy. One way to check the body is to have a blood test. The blood test often uses venipuncture to obtain the result. The nurse or emergency medical technician would the one who use the venipuncture. The problem with venipuncture is that the vein must be located even sometime experienced nurse could have problems with it. Not only that, multiple times of unsuccessful venipuncture attempts will make the next attempts harder as the veins had been damaged also with vessel and tissue forming [1-3].

Transillumination is the passing of light through the walls of a body part or organ to facilitate medical inspection. It could be used to identify and size veins. Also the transillumination could absorb red and near infrared light, then it will scattered back from the skin causing it to be view by observer. Then the superficial veins will absorb all light and appear dark to be visible against the red background by Beer-Lambert Law. Transillumination had been used for many years, including with visible light, to provide vision of subsurface biological structures. The subsurface biological structures include arteries in the foot, hands, and wrists of neonates for injections. In medical, transillumination will be used to find the superficial veins, which included median cubital vein, varicose vein, and to use the venipuncture in infants [4-7].

Molecular oxygen combines with hemoglobin will form an oxyhemoglobin, which is the form of oxygen that goes into the blood. Deoxyhemoglobin defines as hemoglobin without the bound oxygen. The absorption of oxyhemoglobin had lower absorption than deoxyhemoglobin. The absorption rate is 660 nm wavelength as shown in figure 1. The result of the experiment shows that the absorption rate will depend on hemoglobin in the blood. From the research, it could be found that the deoxyhemoglobin will absorb light in wavelength of 660-700 nm, but the oxyhemoglobin will absorb light in wavelength of 500-600 nm. [8]

The safety of LED-based on transilluminators in skin had been reported as the temperature could be significant as it is not as hazardous under normal use conditions. This research will aim to design and construct of a compact model of median cubital transilluminator for its convenient usages. The weight will be reduced and will see the vein more clearly by using red light of 660 nm of LED. [6]

OPERATING PRINCIPLE/SYSTEM DESIGN

This research was to use the principle of light absorption of deoxyhemoglobin in vein, transillumination and electronics. The design and construction a compact model of median cubital transilluminator was composed of 3 parts:

![Fig. 1 Absorption wavelength of light between Oxyhemoglobin and Deoxyhemoglobin](image-url)
1. Design and construction of the compact model of median cubital vein transilluminator

The design and construction of the compact model of median cubital vein transilluminator was composed of head of the light source and the handle which used Rhinoceros 5.0 Evaluation software for design model.

The head light source of the device was C-shaped in order that the incident light from LED was clear to shine and no shadows covered on an area that the light shined. The C-shaped had radius 26 mm and the length of curve was 75 mm and it had a panel of LED within. The panel of LED lamp which used to connect 20 LEDs with the control brightness circuit.

The handle of the device has a rounded curve shape in order to comfortable holding. At the handle had a sliding switch for turning on and off the device and adjusted the brightness of the LED lamp and there was also a control brightness circuit of the LED bulbs and battery contained within.

The body of a compact model of median cubital vein transilluminator used by Rhinoceros 5.0 Evaluation software shown in Fig. 2.

2. Design and construction of the control brightness of light source circuit

The design and construction of the control brightness of light source circuit which was composed of power supply part used battery 9 volts 550 mAh to generate electric voltage to the circuit, control switch part and light source part was used LED wavelength 660 nm.

The block diagram of the design and construction of the control brightness of light source circuit was shown in Fig. 3.

![Fig. 2 Model of a compact model of median cubital vein transilluminator](image)

![Fig. 3 Block diagram of the design and construction of the control brightness of light source circuit](image)

A. Design and construction of the power supply part

The design and construction of power supply part had to use a single battery which generated DC current to the LED driver circuit. The DC current which used in LED driver circuit was 58 mA, Therefore a battery which was suitable applying to the LED driver circuit was 9 volt 550 mA. A single battery could be available for 10 hours to apply electric current to the circuit.

B. Design and construction of control switch part

The design and construction of control switch part was composed of the control switch and the adjustable brightness circuit which was used to adjust the brightness such as turn on, turn off, increase or decrease the brightness by sliding a control switch in order to see the vein suitably. The design and construction of control switch part was shown in Fig. 4.

The design and construction of control switch part used LM 555 by generating Pulse Width Modulation (PWM) which determines the frequency of the circuit was 1 kHz and used the variable resistor 10kΩ to apply in equation (1) for finding the capacitance. The capacitor was used in control switch part was 100 nF which could find as follow.

\[ f = \frac{1}{RC} \]  
\[ 1 \text{kHz} = \frac{1}{(10kΩ)C} \]  
\[ C = 100 \text{nF} \]

C. Design and construction of light source circuit

The light source used to illuminate vein and intensity of light affects to see the blood vessels clearly. Therefore this research was used the wavelength 660 nm of red LED which was suitable for seeing vein clearly. The equations which used to calculate the highest number of LED usage in series circuit, the total voltage of LED circuit and the resistance of the circuit in order to use to design about connecting LED circuit as shown in equation (2), (3) and (4)

![Fig. 4 Design and construction of control switch part](image)
• Calculate the highest number of LED usage in series circuit

\[
\text{Number of LED} = \frac{E}{V_{F_{LED}}} \quad (2)
\]

When \( E \) is Voltage of the circuit (V)  
\( V_{F_{LED}} \) is Dropout Voltage of LED (V)

• Calculate the total voltage of LED circuit

\[
\text{Total Voltage of LED} = LED \times V_{F_{LED}} \quad (3)
\]

When \( LED \) is Total number of LED  
\( V_{F_{LED}} \) is Dropout Voltage of LED (V)

• Calculate the resistance of the circuit

\[
\text{Resistance in the circuit} = \frac{E-V_{LED}}{I_R} \quad (4)
\]

When \( E \) is Voltage of the circuit (V)  
\( V_{LED} \) is Total voltage of the LED (V)  
\( I_R \) is Electric Current which pass through LED (A)

The design circuit of the LED was used with red LED light, which provided a wavelength of 660 nm. The size of the bulb was 5 mm each, and there were 20 bulbs in total. All of them would be connected through series circuit, which were 4 bulbs per series, total of 5 sets. Then each set were connected by parallel circuit. From the description of LED, it stated that there would be a forward voltage of 2.2 Volts and a forward current of 20 mA. Both of this would be connected in series circuit in 5 sets. Each set had a voltage of \( 2.2 \times 4 = 8.8 \) V, which could be concluded that the power source of this project would be the electrical battery of 9 V. The LED could be connected directly through the battery, which didn’t require the need of resistance to be connected via series circuit to limit the electric current in each LED. The Fig.5 showed how the circuit was connected.

Fig. 6 The integrated circuit of the transilluminator

The design of the integrated circuit of the transilluminator was shown in Fig.6.

The total LED will be setup on the panel. The panel shape was like the C letter which had the outer diameter of 59 mm and the inner diameter of 52 mm. The thickness was 2 mm and there was a space for the operative for 27 mm. The LED would be placed onto the panel with the space between of 0.18 cm, which the space would be for the heat ventilation when the LED was turned on. The Fig.7 showed the LED panel design.

The compact model of median cubital vein transilluminator was designed by using the light source of letter C with a plastic handle. The red LED light with 660 nm wavelength, size of 5 mm, and 20 bulbs. The bulbs were connected by series with 4 bulbs each set and a total of 5 sets. The LED was placed on the panel with 80 degree from the surface. This allowed the illumination to cover median cubital vein or the area needed to focus. Also the additional 60 degree angle for the venipuncture and it would be there to make the operation easier for medical practitioner. The space would be 2.6 cm away from the center point of the panel. The area for venipuncture would be 2.7 cm. The handle would be 68 cm and the length of the transilluminator was 136 cm. There would be 2 circuits in the device, which are light source circuit, and circuit for adjustment, respectively. Fig.8 was shown the circuits inside the compact model of median cubital vein transilluminator.

Fig. 7 Design of LED panel

Fig. 5 The design of light source circuit
RESULTS AND DISCUSSION

The results of design and construction of a compact model of median cubital vein transilluminator had details as the following:

1. The feature of the compact model of median cubital vein transilluminator which was designed and constructed consist of 9 Volt battery, which was a power source, head light source, on and off switch and light adjuster. Fig. 9 had shown the compact model of median cubital vein transilluminator.

2. The characteristic of a compact model of median cubital vein transilluminator was designed and constructed for the usage of seeing the vein at the median cubital vein. The ability was to see the clearer image of the median cubital vein. The 9 Volt battery source was used. The device was small, compact shape and can be carried easily. The light source was a C-shape which used LED of 660 nanometer of wavelength. It had an ability to adjust the light for the use of seeing the vein.

3. The functional test of a compact model of median cubital vein transilluminator found that when the light intensity was measured on the skin surface, the light intensity was between 1200–3500 lux. The samples with pale skin could be seen the median cubital vein easily. The colored skin and fat people must use a higher light intensity in order to see the median cubital vein. The compact model of median cubital vein transilluminator will make more convenient for the medical practitioner to see median cubital vein. While the compact model of median cubital vein transilluminator was used to illuminate the median cubital vein, we can see the median cubital vein more clearly as shown in Fig. 10.

4. The result of satisfying test of user who used the compact model of median cubital vein transilluminator was shown in Table 1.

<table>
<thead>
<tr>
<th>The result of satisfying test of user</th>
<th>Mean</th>
<th>Meaning</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. The device is nice.</td>
<td>4.20</td>
<td>Very good</td>
</tr>
<tr>
<td>2. The device is suitable size.</td>
<td>4.00</td>
<td>Very good</td>
</tr>
<tr>
<td>3. The device is strength shape.</td>
<td>4.20</td>
<td>Very good</td>
</tr>
<tr>
<td>4. The device is easy to maintenance.</td>
<td>4.00</td>
<td>Very good</td>
</tr>
<tr>
<td>5. The device can change battery easily.</td>
<td>4.40</td>
<td>Very good</td>
</tr>
<tr>
<td>6. The spares of the device are found easily.</td>
<td>4.30</td>
<td>Very good</td>
</tr>
<tr>
<td>7. The component of the device can be easy for fixing and changing.</td>
<td>4.10</td>
<td>Very good</td>
</tr>
<tr>
<td>8. The device can be set easy.</td>
<td>4.00</td>
<td>Very good</td>
</tr>
<tr>
<td>9. The device can be moved easily.</td>
<td>4.40</td>
<td>Very good</td>
</tr>
<tr>
<td>10. The device has safe for using.</td>
<td>4.20</td>
<td>Very good</td>
</tr>
<tr>
<td>11. The device has a light weight.</td>
<td>4.30</td>
<td>Very good</td>
</tr>
<tr>
<td>12. The device can used for seeing vein clearly.</td>
<td>4.50</td>
<td>Very good</td>
</tr>
</tbody>
</table>

Mean | 4.22 | Very good |

Fig. 8 Circuit inside the compact model of median cubital vein transilluminator

Fig. 9 The compact model of median cubital vein Transilluminator

Fig. 10 The result of functional test of a compact model of median cubital vein transilluminator
From the table 1 found that mean of user opinions about the compact model of median cubital vein transilluminator were found to be 4.2 which was very good. The top performance of the compact model of median cubital vein transilluminator were the device can used for seeing vein clearly was 4.50 which was very good. The reason behind this score was not a perfect score was from the survey from asking the real user. As this device could see the vein clearly, but as the brightness was too bright, it may cause some blur in the user’s eyes, when it was used for long time.

CONCLUSION AND DISCUSSION

In this research, we designed and constructed a compact model of median cubital vein transilluminator which use a diameter 5 millimeter of LED with 660 Nanometer wavelength as the light source. There are 20 LEDs altogether. The character of the LED is durable, reduce electric cost, brighter light, lower heat, and it is safe for human skin. It is used to do the transilluminator for the median cubital vein in order for the medical practitioner to easily see the vein and put the needle accurately. The transilluminator could be adjusted with the brightness. The cost of the device is low and the size is small, which is convenient by travelling. Mean of user opinions the compact model of median cubital vein transilluminator were found to be 4.22 of 5 points. The feedback from the user were very good.

ACKNOWLEDGMENT

Thank you Faculty of Biomedical Engineering, Rangsit University and Assist.Prof. Sema Sornprasom for supporting and providing the facilities during to do this research, thank you Yuppaede Phusirimongkhonchai, Kanokporn Phosri for helping this research.

References