Georgian Technical University

Manuscript

Tohid Talebifar

Designing Mobile Transilluminator Vein Finder

Submitted for the academic degree of Doctor of Engineering

Doctoral Program “Biomedical Engineering”

Code: 04

Summary

Tbilisi 2020

The thesis was developed at the Department of Biomedical Engineering of the Faculty of Informatics and Control Systems of Georgian Technical University

Academic Supervisor: Professor Irine Gotsiridze

Reviewer ________________________________

Reviewer_________________________________

Reviewer_________________________________

The thesis defense will take place at the session of the board of the dissertation council of the Faculty of Informatics and Control Systems of Georgian Technical University, on building ----------------

Auditory----------------- Address: 77 Kostava, Tbilisi, 0160

The thesis is available at the GTU librairy,

the abstract - on the Faculty webpage.

The Secretary of the Dissertation Council: Professor, Tinatin Kaishauri

General Description of the Work

Topic. Around Up to 80% of all patients admitted to hospitals worldwide will have a peripheral intravenous line inserted in the forearm or hand to administer fluids, medications, and blood products. Sometime this procedure can be difficult for paramedics or others in such cases like infants and elderly people, as well as in obese patients, dark skinned people, intravenous drug abusers, hypotensive individuals, and those with multiple injuries that limit the number of available limbs and may require several attempts, causing distress. Difficult venous access affects more than one-third of patients at hemophilia treatment centers.

Vein finders are devices that we use in order to helps medical staff to reduce risky issues and also decrease the number of time that we try to find the veins. Many devices developed there are 2 main technology in Biophotonics devices first using visible light second near infrared (NIR) light. Each devices have advantages and disadvantages. Near-infrared light devices might be efficacious in selected subpopulations, but the available evidence does not support an overall benefit in the pediatric population. Transilluminators modestly improve pediatric peripheral intravenous catheters (PIVC). On the other hand, visualization in NIR devices is main issues. Some devices use monitor or display to show us vein map some of them project the map of vein on hands. These processes increase the price and complexity of device. Last studies show that we could not find out overall benefit of using near-infrared light devices for pediatric peripheral intravenous cannulation. But, this device might be useful for the patients in a difficult condition of successful cannulation. The current dissertation therefore conducts further research in a developing on IR Phototransistor sensor to detecting veins we also compare our devices with Transilluminator device. Our goal is to develop a device that helps medical staffs during intravenous (IV) procedure to find veins with minimal design and economic price for competitive market.

Objective. Our goal is to develop a device that helps medical staffs during IV procedure to find veins with minimal design and economic price for competitive market based on IR Phototransistors technology.

Methodology. Device must have to main features; first it can detect veins; second must be portable or has minimal design. For First feature we use scientific method. We used IR phototransistor as a detector and IR LED (~ 940 nm) as light source. The IR Phototransistor that we used, has effective performance on 5 volts (DC), we have also use Red LED as indicators connected in series with IR Phototransistors, we measure voltage drop between Red LED leads, this voltage drop leads us to indicate location of vein on hand by plotting this voltage drop versus vertical axis on vein stream we can achieve a voltage deflection on vein position. This voltage deflection can be used as a signal to create visualization for vein location. For second feature we used Design methodology. we used Minimal and simplicity design theory in our structural model to strip down our design to fundamental elements as possible as we can, to reduce material and manufacturing cost of our device which means; Strip down our design to fundamental elements and Simple functionality and user interaction.

The main results of the work and scientific innovation. There are different methods to find veins we chose biophotonics approach. In this method we use visible lights and also IR radiation to find veins. We developed 2 type of devices. First one uses Visible Red/Yellow light source (Red/Yellow LEDs) to locate veins, second one uses IR light (IR LED) to locate veins on hand. Our goal in this thesis is to design devices that have simple or minimal design in order to decrease the price of this type of devices in the market. For Visible light source device, we used "Modular design" approach. Modular design is a design approach that creates things out of independent parts with standard interfaces. This allows designs to be customized, upgraded, repaired and for parts to be reused. A well know example of module design are LEGO plastic construction toys. For IR one we use phototransistor as a sensor and detectors to find veins. By using phototransistors, we measure intensity of reflected IR light from Dermis of skin. We know that IR lights (~940 nm) can penetrate into the skin more than 5 mm, and we know that Hb_s can absorb more IR lights compare to surrounding tissues. So we measure voltage drop through the indicators LED when the IR source and IR detector (IR phototransistor) get align with vein stream, voltage across the indicator LED drop it significantly so we can realize that we are on the vein. The interesting thing is that based on size of vein the intensity of indicators LEDs changes differently so with this method that is kina spectrophotometric approach we can even measure the size of vein. Note that the device that we developed in this project is analog by using microcontroller and display such as LCDs we can even visualize veins. The important thing about IR Phototransistors is that they give us better output signal compare to photodiode and they are just sensitive to IR radiation.

Volume and Structure of the Work. Dissertation consists of literature review, results, conclusion and Appendix. It is 117 pages long and has 37 references. It introduces Designing of mobile biophotonic vein finder for IVs in clinics and hospital. Chapter1 discusses about Basics of Biophotonics. Chapter2 is an overview of Methods of Vein finding in PIVC. Through two chapters, chapter 3 and 4, I discussed methodology that we use in design of Biophotonics Vein Finder (BVF) device and how we can have documented it. In the results section, I described how I designed BVF devices (visible & IR photo-sensor) and results of testing devices on different cases. Also in appendix I added Biophotonic Vein Finder guideline for further information.

Abstract

Chapter 1. In this section basics of Bio-optics was described. We start to have an overview of Biophotonics field then we talk about cell biology and continue this chapter to Components of optical systems. Each optical system has 4 main components; Light source, a medium that light propagates, such as air, water, or glass or skin in our case, a medium or components to manipulate light, such an as a lens to focus it, a shutter or a “light switch” for communication, or a fiber-optic cable to

guide light and A detector, such as the cones and rods on the retina, a photo detector array used in a digital camera, or a light-sensitive film for analog photography. We discussed each components and then we finish this chapter with Interaction of Light with Matter.

Chapter 2. In this chapter we review Methods of Vein finding in PIVC. We discuss modern methods for finding veins such as Ultrasound (US), Near infrared (NIR) spectroscopy, Visible light transilluminator, Pressure sensor, Multispectral camera and recently developed robotic systems. We finish this chapter by focusing on Visible light transilluminator and introduce some of the best devices in market.

Chapter 3. In chapter 3 we talk about Methodology that we use in our paper. Our work is based on Design process method. The Design Process is an approach for breaking down a large project into manageable chunks. Architects, engineers, scientists, and other thinkers use the design process to solve a variety of problems. We discuss this approach and different phase of designing. Also we talk about Sustainable Design and Strategy for sustainable design. We finish this chapter with Human-centered design (HCD) as an engine and inspiration for us.

Chapter 4. In this chapter we discussed Designing Vein finder. We start with Define the Problem phase and then based on Problem (need) statement table we start to collect data and understand the target users, then we start to study similar product in market and analyzing the product that we want to design ant the end of this chapter we try to have brain storming and analyzing our ideas.

Chapter 5. Results. In this section we introduce and describe our design for BVF device in detail. First we have an overview of Optical Vein Detection Systems then we describe structure of our device and represent our model. Then we start practical parts of our work about illumination experiment, method of prototyping and testing the device on different cases and analyzing the results. Then base on our results from visible transilluminator and NIR camera. We developed new type of IR phototransistor in a purpose of detection of veins.

Appendix. In the appendix we add a guideline that represent a procedure for designing Biophotonics vein finder device for doctors, nurses, paramedics or any person who wants to find veins in a cheapest and fastest way.

<u>Theory:</u>

The unique characteristic of NIR radiation is it can penetrate into biological tissue up to a depth of about 3 mm, in which the veins are located. Arteries are more deeply seated than veins and NIR cannot penetrate further beyond 3 mm. Moreover, in contrast with arterial blood which is mostly occupied by oxygenated hemoglobin (HbO2), the reduced, or deoxygenated, hemoglobin (Hb) in the venous blood absorbs more of the radiation in this spectrum than the surrounding tissue. This concept is illustrated in Fig. 1 [2], which describes the absorption spectra of Hb and HbO2 and water, main component of the neighbor tissues such as fat, and muscle. According to the figure, only Hb and HbO2 are the primary absorbers of NIR light (600–1300 nm). In this region, venous blood still maintains a higher absorption capability when the absorption coefficients of both oxygenated and deoxygenated blood dramatically fall with the wavelength beyond 600 nm. Also, there exists a peak at approximately 760 nm for HbO2, and the absorption difference between both kinds of hemoglobin is most prominent within the 700– 900 nm range. Therefore, it is significant that the wavelength of the NIR light source is chosen to be between 700 and 900 nm or around 760 nm, ideally.

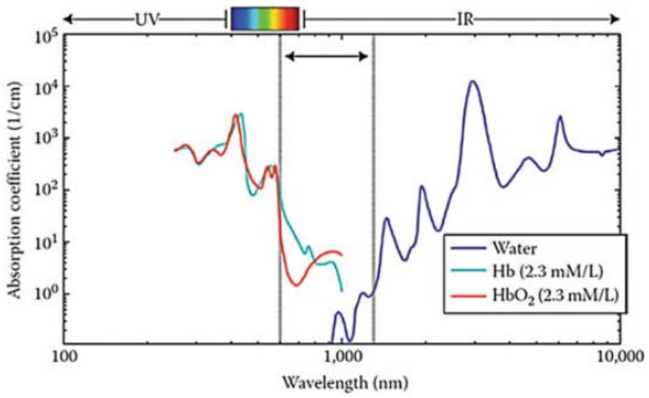


Figure 1. The absorption spectra of water, Hb, and HbO2

Now based on this theory we make 3 types of vein detection systems. 2 of them are already on the market one of them is our proposal to make IR photo-sensing sensor for vein detection.

Visible Transilluminator Device:

This simple technology is based on LED (light emitted diode) light waves that penetrate tissue, are absorbable by hemoglobin, and are visible to the human eye. The skin reflects the short-wavelength light (blue and green) and absorbs the long-wavelength light (orange and red). The intensity of the light reflected from the surface of the skin overpowers the transmitted light, limiting the naked eye's visualization of superficial veins. Reflected light is reduced and deeper veins visualization is increased by applying LED light waves, which are easily absorbed by deoxygenated hemoglobin in venous blood and show up as dark areas on the skin. An improvement to this method, side-transillumination, uniformly transilluminates a small region of the skin to obtain better imaging of veins without shadows, and enables penetration of light into tissue for vein imaging up to 6 mm in depth, depending on the size of the vein.

Structure of Device:

The device has 2 main parts;

1- Rounded Section: Rounded circle structure that Red LEDs for illumination locate on that part.

2- Battery Section: we will use 3 volts' coin cells batteries for powering device.

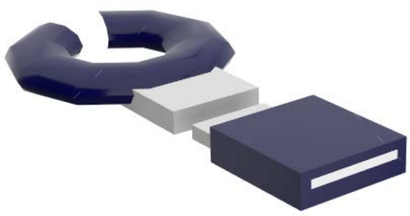


Figure 2. Conceptual 3-D model of device. (Design by https://www.vectary.com)

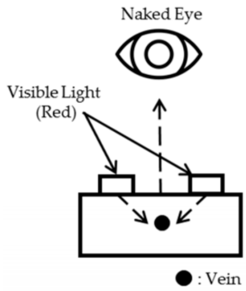


Figure 3. Penetration side-transillumination method.

Electronics of device: LED is simply a special version of a diode that comes with transparent plastic packing (so that it can emit light) and is optimized for generating light at a certain wavelength (or color). In short, LEDs are like tiny light bulbs. However, LEDs require a lot less power to light up by comparison. They're also more energy efficient, so they don't tend to get hot like conventional light bulbs do.

Results:

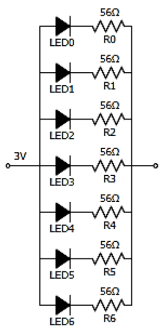
Number of LEDs	7
Supply voltage, V_s	3V
LED forward voltage, V_f	2V
LED forward current, I_f	20mA
Individual Diode Power Dissipation	40mW
Total Diode Power Dissipation	280mW
Recommended Resistor Wattage	1 Watt Resistors
Solution 1	 Current Draw: 140mA

Figure 4. Technical data for electronic part.

How to use the Device: Here in the following picture we can see how to using device to find the veins also we put some pictures of the results of device.

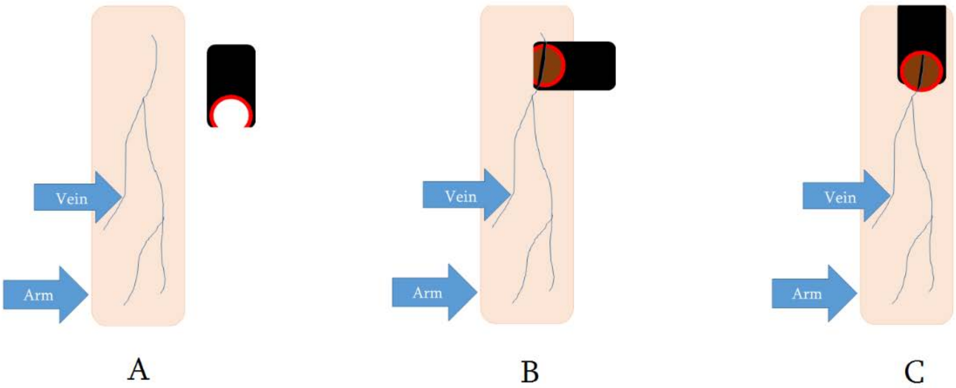


Figure 5. Procedure of finding vein

As you can see in figure 90.;

A. First turn on device,

B. use devices perpendicular to the arm bone and go up and down to find shadows (veins), C. then when you find best vein for injection you need to turn the devices parallel to arm bone and do the injection.

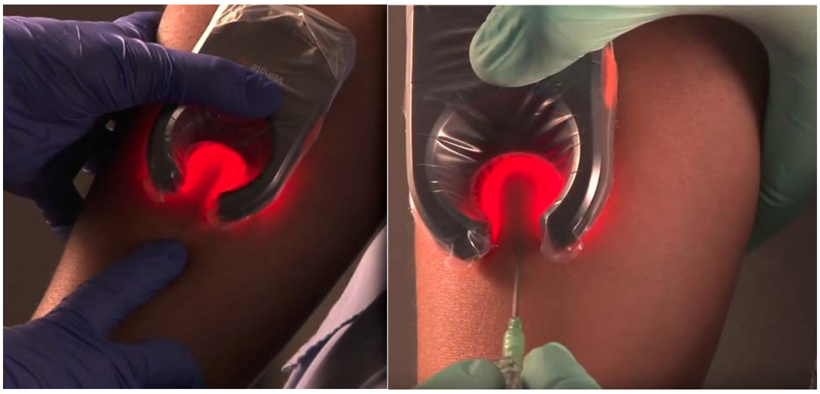


Figure 6. How we handling device when we want to do injection into the vein. (Veinlite®)

Results of Visible Transilluminator Device: As you can see our goal in BVF devices is make distinguishable contrast between vein and sounding tissues so we can see vein as a dark shadow in Field of View (FoV) region. We test on more than 20 cases. For 15 case we took picture before using device and after using device. For Red light we can visualize deep vein (not more than 5 mm depth) as a Blur shadow.

For yellow light we can see clear shadow with clear border but not so deep. We can say that for more wave length (λ) we have deeper penetration but lees quality of visualization or it's better to use image sharpness/blurriness factor. We can say that;

$$\lambda \text{ (wave length)} \propto d \text{ (Penetration)} * \sigma\text{(Blurriness factor)}$$

It seems that base on testing on different person both of lights can be use but in some cases with tiny veins yellow light work better than red one. We cannot find any specific pattern between BMI of person and color of light for finding veins. About skin color definitely in white color it is easier to find veins because of contrast of veins with surrounding tissue even without using device but the main factor is vein pattern of arm. In some cases, vein pattern is in deeper part of skin so we need to dim the light and try to find a deep blur shadow that has a signaling fluid behavior. How we can distinguish between fake shadow and true one is that true shadow has a behavior like fluid it is disappear and appear light fluid flow. Fake shadow appear and disappear instantly. We can say that true shadow is flowing and fake ones are moving instantly. The reason is that the true shadow is result of absorbing the light by Hbs and Hbs are flowing in veins.

Here we can see some of the results when we use BVF device.

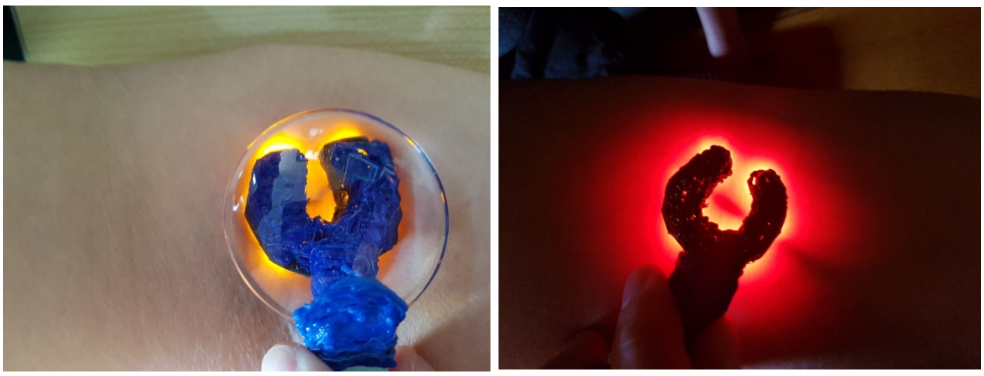


Figure 7. Left: Using yellow lights (BVF_Y). Right: Using Red lights (BVF_R), Sm/WB, A19, W130, and H182.

Figure 8. Using yellow lights (BVF_Y), Sf/W, A27, W55, and H167.

NIR Camera Spectroscopy

_In this method we use near infrared light (700-900 nm) they can penetrate deeper than visible lights. In this type of device, we can see veins on monitor or in some models they can project pictures on our arms.

Structure of device: At figure 10. You can see the schematic of experiment we use 4 NIR LED- 5mm. (You can see technical data shit of this type of NIR LED on this site: https://dac.ge/pdfs/02614.pdf

Here at figure 11 you can see the results of using NIR spectroscopic camera method to obtain vein location on forearm.

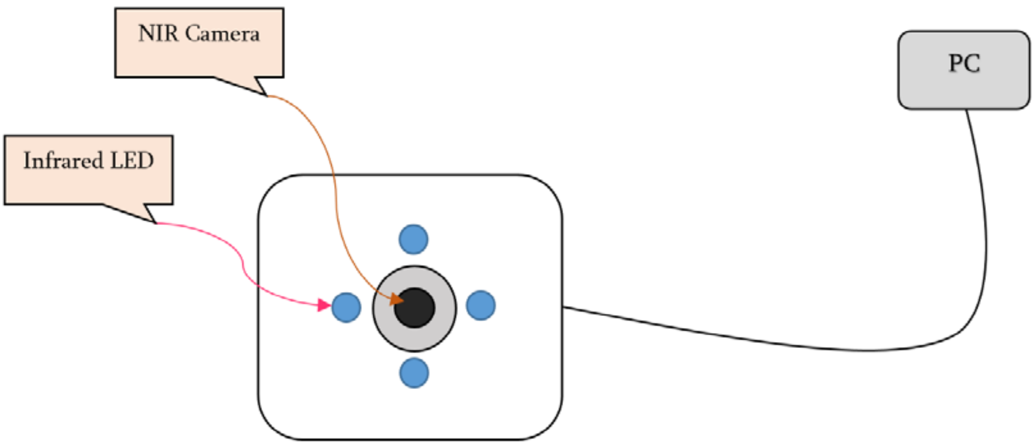


Figure 9. Structure of NIR camera system

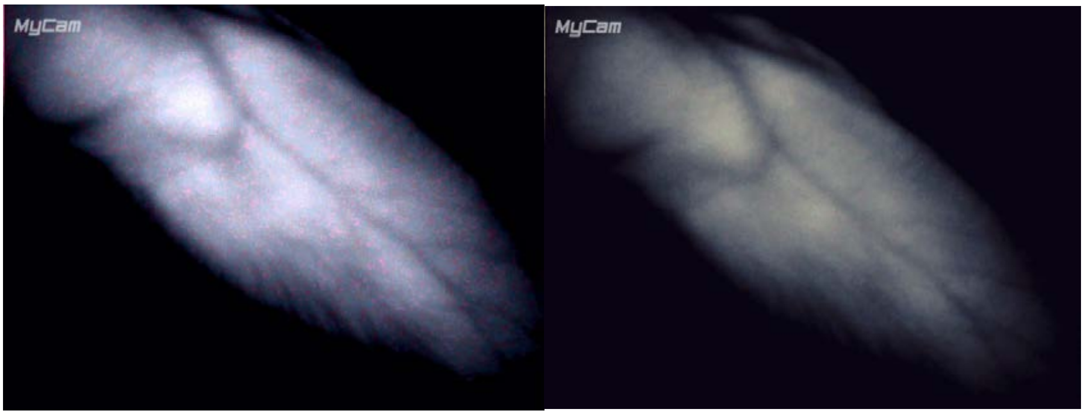


Figure 10. Results of using NIR spectroscopic camera method to obtain vein location on forearm, using different filters.

IR Phototransistor vein detection device

Here now we represent our method to detect vein through using IR Phototransistor and compare it with visible transilluminator device.

The main idea is that veins can absorb more infrared compare to its surrounding tissues.

A phototransistor is an electronic element that relies on light as the gate control mechanism and current regulator. Most phototransistors are made in the form of a bipolar transistor, meaning that the base-collector-emitter structure is used. The main difference is that the base semiconducting material is designed so that it is sensitive to a light source. As photons enter into the base structure, they are converted into a current flow that acts as the BJT base current that acts to enable the transistor.

The phototransistor is housed in a transparent casing to allow for easy light passage. Often, they have casings that help to enhance and focus light entry to the critical and sensitive components of the transistor. When the base current is formed from light entry, this allows a large amount of current to pass from the emitter to collector.

Since light acts as a switch in the case of a bipolar phototransistor, these devices are used in many electrical circuits that have important light sensitivities.

This could include fire alarms and computer equipment like CD players or infrared devices.

In this method we use one IR Phototransistor that is sensitive to IRs and one IR Leds as a light source. In figure 55 & 56 you can see circuit diagram and structure of device respectively.

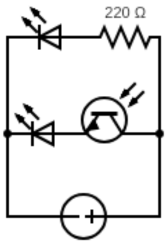


Figure 11. Circuit diagram of IR Phototransistor vein detection

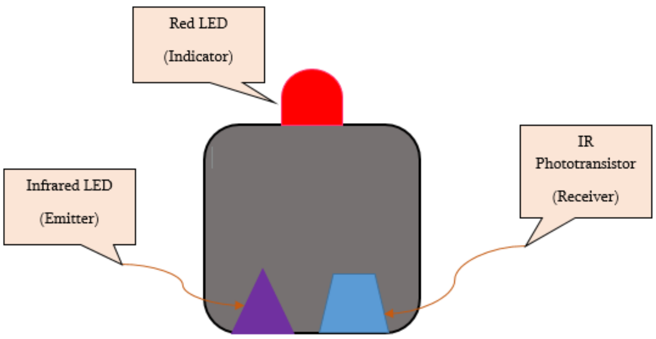


Figure 12. Structure of IR Phototransistor vein detection device

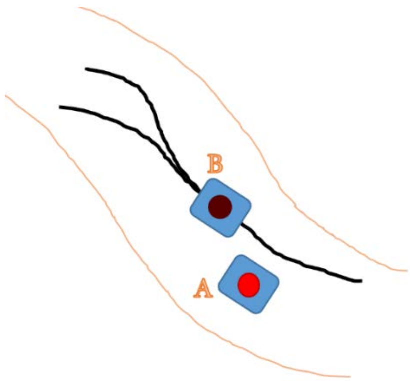


Figure 13. Procedure to find vein.

As you can see in figure 57 when we put device on the top of the vein position because most of IR radiation is absorbed by vein, so we have less current between collector and emitter of phototransistor and the intensity of indicator LED decreases. In figure 58. You can see the results of IR Phototransistor vein detection on forearm and leg.

Figure 14. On the top is a forearm of a female and at the bottom there is a leg of a male case. From left to right; Left: Without using device, mid: using device in a place that there is no vein (we use is as a reference indication), right: when us put device on the top of the vein (as you see the current and following that the intensity of indicator decreases.

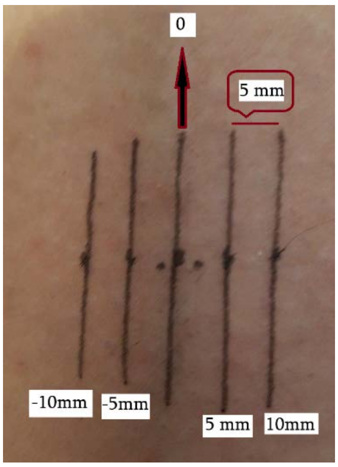


Figure 15. We set vein as a zero point (X=0) then each 5 mm away from vein in both side we check the device and measure voltage drop across the indicator LED.

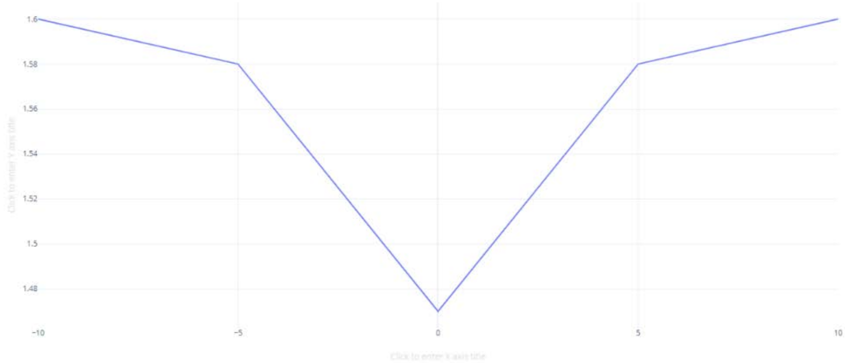


Figure 16. Voltage drop across the indicator led vs. location of device from vein. As you can see at zero points the voltage drops from 1.60 v (reference point) to 1.47 v which means veins absorb more IR so less IR can reach to photo-sensor.

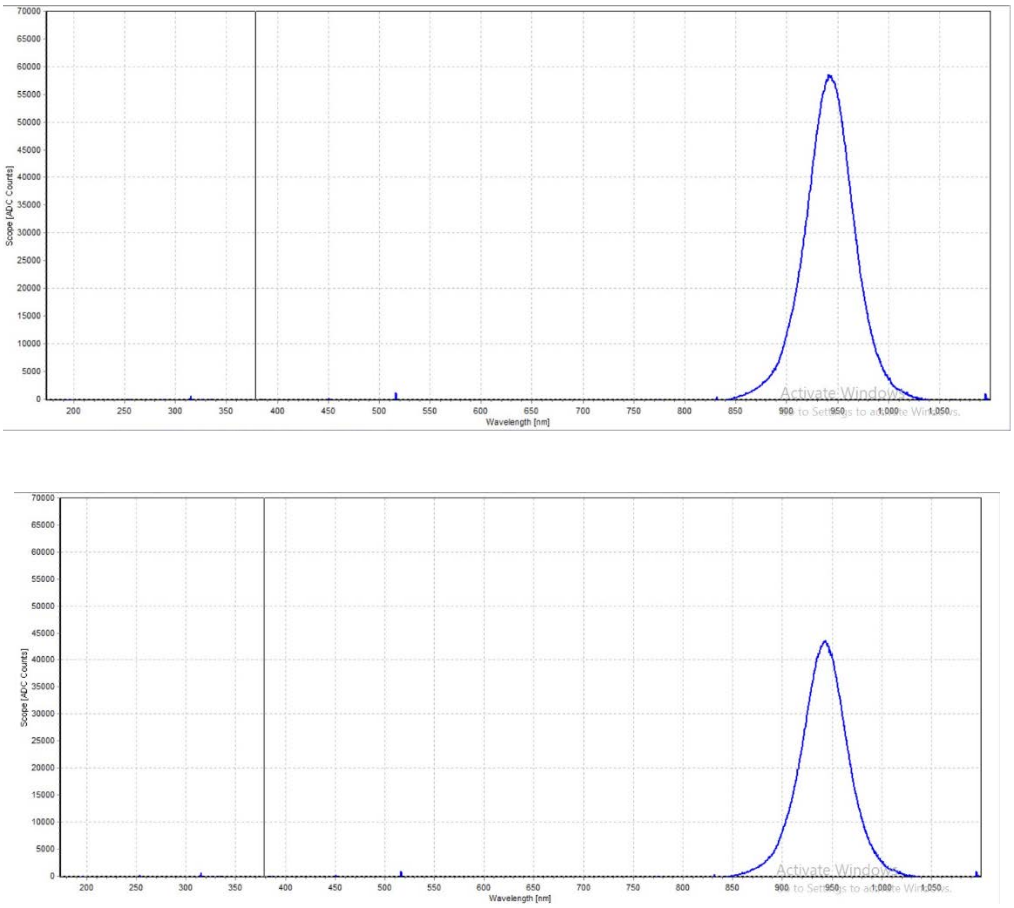


Figure 17. Spectrophotometry of IR LED that we use in our devices as a source when we applied 20 mA (up) and 15 mA on its leads. As you can see we use NIR around 940 nm as a source light. (Measured at Vladimir Chavchanidze Institute of Cybernetics of the Georgian Technical University).

How to construct Visual image for IR Phototransistor vein detection?

For constructing a visualization for our device we can use 10 Segments bar graph arrays as you can see in Figure 66. Each LEDs segment is connected to IR phototransistor circuitry. When any IR phototransistors located above a vein the result is voltage drop across the corresponding leds indicator leads and we can see it as result of decreasing in intensity of LED light. Not that using 10 segment of bar array is an example of how we can visualize veins location in IR phototransistor in real practical work we can have our own indicators array based on modify scales for using on hand. (Like Figure 67.)

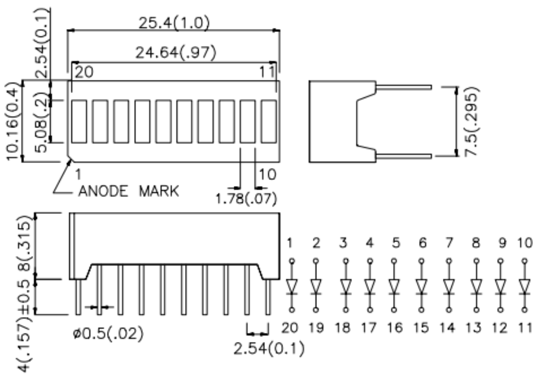


Figure 18. Package Dimensions & Internal Circuit Diagram of 10 segments bar graph arrays.

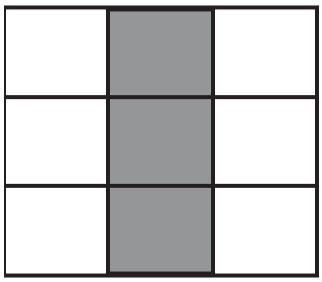


Figure 19. As you can see we can make our own segments array based on our need to use in vein detecting as you can see if all 3 middle segments located align on vein stream we can see vein stream as a shadow on segments arrays.

Conclusion

Here we listed main important results of our study:

1. For Transilluminator Device both red light and yellow light, can be used for finding veins. Based on different patterns of veins in different cases, one of them or both of them, can be used but for tiny veins yellow light has better results. With yellow light we can see branches of veins also, but in practical issue, sometime just finding the main branch is enough, for us to do injection. So based on situation we can use one of these lights.

2. In Transilluminator device for faster performance and reduce costs and materials we have separated power source of device means battery from transilluminator arm. So with one power source and two type of transilluminator arms we can replace trans-arms whenever we need it.

3. Biophotonic visible vein finder we can detect veins as a dark shadow in FoV. Categorize noises in our system 2 type of noise we have; one is Fake shadow and second is Shiny effect. For avoiding these two noises device must work in dim light. We can make separation from fake according the result of absorbing red light by Hb appear and disappear as a flowing darkness or signaling darknes, but fake shadow can appear and disappear instantly. We can distinguish Vein's shadow from fake's one by knowing this fact that fake shadow can apear and disapear instantly, but vein's shadow can move like fluids.

4. We used the "Modular design" approach. Device consists from independent parts with standard interfaces. This allows designs to be customized, upgraded, repaired and for parts to be reused.

5. Using IR phototransistors, as an option alongside other technologies, can help medical product designers to design competitive product to make portable device by reducing the size of device. Portability is main issue for vein detector devices due to IVs procedure condition.

6 . For tiny vein it is too hard, to understand current attenuation we need, to work on sensitivity of device in IR phototransistor vein detection. Best option for tiny veins is, using visible yellow light transilluminator device. IR phototransistor device work based on Spectrophotometry principle, so results show us, that different veins based on size, can give us different signal, this can be used to measuring the size of vein.

Publications and Conference Participations

1. Tohid Talebifar, Irina Gotsiridze, Illumination Design in Transilluminator Vein Finder, Intellectual, 2019, 38, 170-175

2 Irina Gotsiridze, Paata Kervalishvili, Tohid Talebifar, Controlling in Modern Drug Delivery Systems,Nano Studies,2016,13,251-256

3. Tohid Talebifar, Irina Gotsiridze, Sina Talebifar, Concept Design of Low-Cost Handy Transilluminator Vein Finder, Transactions, Georgian Technical University

,Automated Control Systems,2019,57-63.

4.Irina Gotsiridze, Tohid Talebifar, Design Statement For Better Ergonomic Handling For Optical Vein Finder ,GTU and UniFg 1st Joint R&D International conference – JoRDI, "Dynamics and recent trends of vary industries in EU and Georgia: ICTs adoption in supply chain management", 2018, 17-19 October GTU, Tbilisi, Georgia.

5. Irina Gotsiridze, Tohid Talebifar, Sustainable Design of Mobile Transilluminator Vein Finder Device, The Eleventh Japanese-Mediterranean Workshop on Applied Electromagnetic Engineering for Magnetic, Superconducting, Multifunctional and Nanomaterials (JAPMED'11), 16-19 July, 2019, BSU, Batumi, Georgia.

რეზიუმე

მთელ მსოფლიოში საავადმყოფოებში შესულ პაციენტთა დაახლოებით 80%-ს ექნებათ პერიფერიული შიდა არხი, რომელიც მოთავსებული იქნება წინამხარში ან ხელში სითხეების, მედიკამენტების და სისხლის პროდუქტების შესაყვანად. ზოგჯერ ეს პროცედურა შესაძლოა რთული აღმოჩნდეს ექთნებისთვის ან სხვა პერსონალისთვის, ახალშობილების ან ხანდაზმული ადამიანების, ასევე, ჭარბწონიანი პირების, ფერადკანიანი ადამიანების, ინტრავენური ნარკოტიკების მომხმარებელი პირების, ჰიპოტენზიური მოვლენების მქონე პირების, მრავლობითი დაზიანებების მქონე პირების შემთხვევაში. ასეთ სიტუაციებში შესაძლოა საჭირო გახდეს რამოდენიმე უშედეგო მცდელობა, რაც პაციენტში სტრესს გამოიწვევს. ჰემოფილიის მკურნალობის ცენტრების პაციენტების მესამედზე მეტს აღენიშნება გართულებული ინტრავენური პროცედურა.

რადგან PIVC წარმოადგენს ჩვეულ პროცედურას, ადვილად შეიძლება დავივიწყოთ როგორც პაციენტების, ისე სამედიცინო პერსონალის უსაფრთხოების რისკფაქტორებისა და გართულებების შესახებ. პერიფერიული კათეტერების არასათანადოდ მოთავსებით პაციენტებში გამოწვეული ტრავმების გამო ექთნების მიმართ სამართლებრივი საჩივრების რაოდენობა იზრდება, ამასთან, სტატისტიკური მონაცემების საფუძველზე, საკომპენსაციოდ გადახდილი თანხა საშუალოდ აღემატება 100 000 აშშ დოლარს. სარწმუნოდ არის დოკუმენტირებული მონაცემები სისხლძარღვებში მოკლე პერიფერიული კათეტერების მოთავსების შერმთხვევების ზრდის შესახებ. ვენის საძიებელი მოწყობილობები მნიშვნელოვნად ამცირებს ვენის საძიებლად საჭირო დროს. ისინი თავიდან აცილებენ ნემსების, შპრიცების, PICC-ის და სხვა მასალების ხარჯს. ეს მოწყობილობები არაინვაზიურია, რადგან ისინი იყენებენ სინათლის წყაროს კანქვეშა ქსოვილებში ვენების დასანახად. ხილვადი ვენების ბიოფოტონური მაძიებელი იყენებს ხილვად ყვითელ-წითელ სინათლეს ვენების (ზედაპირული ვენების) დასაფიქსირებლად.

მოწყობილობის ამ სახეს ორი უპირატესობა გააჩნია. პირველ რიგში ის იაფია ინფრაწითელ ანალოგთან შედარებით, ამასთან, მარტივია გამოსაყენებლად და საწარმოებლად. ამ ნაშრომში ჩვენ ვცდილობთ წარმოვადგინოთ ამ ტიპის ხელსაწყოს ჩვენეული დიზაინი და მოდელი. ჩვენ ვტესტავთ ორი ტიპის სინათლეს, წითელსა და ყვითელს. ჩვენ ასევე ვცდილობთ გავარკვიოთ ხმაურის წყარო, რომელიც გვხვდება ვენის საძიებელი ამ მეთოდების შემთხვევაში. ჩვენ ვამზადებთ

და წარმოვადგენთ გაიდლაინს ექიმებისთვის, ექთნებისთვის, პარამედიკებისთვის ან ნებისმიერი პირისთვის, ვისაც აქვს ამ მანიპულაციის ჩატარების აუცილებლობა.

ტრანსილუმინატორული მოწყობილობისთვის ვენების მოსაძებნად კვლევაში გამოყენებულ წითელი და ყვითელი შუქი. ვენების სხვადასხვა პატერნების გამო განსხვავებულ შემთხვევაში, შესაძლებელია ერთის ან ორივე მათგანის გამოყენება, მაგრამ წვრილი ვენებისთვის ყვითელ შუქის გამოყენებას უკეთესი შედეგი აქვს. ყვითელი შუქით ვხედავთ ვენების განშტოებებსაც, მაგრამ პრაქტიკულად ზოგჯერ მხოლოდ ძირითადი განშტოების პოვნაც საკმარისია იმისათვის, რომ გაკეთდეს ინექცია. სიტუაციიდან გამომდინარე, ჩვენ შეგვიძლია გამოვიყენოთ ერთ-ერთი ასეთი შუქი.

ტრანსილუმინატორული მოწყობილობების უფრო სწრაფი მუშაობისთვის და ხარჯების შესამცირებლად, ჩვენ გამოვყავით მოწყობილობის ენერგიის წყაროს, ბატარეას ტრანსილუმინატორული მოწყობილობის სახელურში. ასე რომ, ერთი ენერგიის წყარო და ტრანსილიუმინატორი ორი ტიპის სახელურით შესაძლებლობას იძლევა განხორციელდეს მისი ჩანაცვლება კლინიკური სიტუაციიდა გამომდინარე.

ბიოფოტონური ვენების მძებნელით განვახორციელეთ ვენების ვიზუალიზაცი, მხედველობის არეში (Field of View) - ში მუქი ჩრდილის დანახვით, ხმაურის კატეგორიებად დასაყოფად ჩვენს სისტემაში გამოვავლინეთ ხმაურის 2 ტიპი; ყალბი (Fake) ჩრდილი, მეორე კი ათინათის (Shiny) ეფექტით განპირობებული. ხმაურის თავიდან აცილების მიზნით, მოწყობილობა უნდა მუშაობდეს დაბალი განათებულობის პირობებში. ერთ-ერთი ყველაზე მნიშვნელოვანი საშუალება, რომლითაც შეგვიძლია განვასხვავოთ ნამდვილი ჩრდილი ყალბისგან, არის ის, რომ სიბნელე და ჩრდილი, რომელიც Hb- ს მიერ წითელი შუქის შთანთქმის შედეგია, ჩნდება და ქრება, როგორც დენადი სიბნელე, მაშინ როდესაც ყალბი ჩრდილი შეიძლება გამოჩნდეს და გაქრეს მყისიერად .

წვრილი ვენებისთვის საუკეთესო ვარიანტია ყვითელი შუქის ტრანსილუმინატორული მოწყობილობის გამოყენება. IR ფოტოტრანზისტორული მოწყობილობის მუშაობა დაფუძნებულია სპექტროფოტომეტრიის პრინციპზე, ასე რომ, შედეგი გვაჩვენებს, რომ სხვადასხვა ზომის ვენებმა შეიძლება მოგვცეს სხვადასხვა სიგნალი, რაც შეიძლება გამოყენებულ იქნას ვენის ზომების დასადგენად.

გამოვიყენეთ "მოდულური დიზაინის" მიდგომა მოწყობილობის შესაქმნელად დამოუკიდებელ ნაწილებისგან, რაც საშუალებას იძლევა განხორციელდეს დიზაინის მორგება, განახლება, შეკეთება და მათი ნაწილების ხელახლა გამოყენება. IR ფოტოტრანზისტორებზე დაფუძნებული ვენის ტრანსილუმინატორული მძებნელი შეიძლება დაეხმაროს სამედიცინო პროდუქტის დიზაინერებს შეიმუშაონ კონკურენტული პროდუქტი, პორტატული მოწყობილობა ინტრავენური პროცედურების ჩატარების მიზნით

ჩვენს მიერ შესრულებული სამუშაოს შედეგები შეიძლება გამოყენებულ იქნას ქვეყნებსა და რეგიონებში, სადაც რესურსების ნაკლებობაა ჯანდაცვის სფეროში. ჩვენ ვიყენებთ 3-D კალამს ჩვენი ხელსაწყოს პროტოტიპის შესაქმნელად, ასევე შესაძლებელია გამოვიყენოთ 3-D პრინტერები ამ ხელსაწყოს საწარმოებლად. 3-D კალმის გამოყენების უპირატესობას წარმოადგენს ის, რომ ეს მეთოდი იაფი და მარტივია გამოყენებაში. ინსტრუქცია, რომელიც დანართის სახით ახლავს ნაშრომს დამუშავებულია მომხმარებლისთვის. ამ ნაშრომში ასევე წარმოდგენილია საძიებო მოწყობილობის საფუძვლები მომავალი სამუშაოსთვის და თანამედროვე მოწყობილობებისთვის, რომელიც საშუალებას იძლევა დამზადდეს მოწყობილობა ადგილობრივად ან ნებისმიერ სხვა ქვეყანაში, რომელიც საჭიროებს სამედიცინო მოწყობილობების დამუშავებას კონკურენტუნარიან ფასებში.