

Design Research Seminar Report

‘Comparative study of vein detection devices to
develop a low cost device’

By Trivikram A
136130013

Under the guidance of
Prof. Girish Dalvi

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ABSTRACT

Vein detection technology is a vital area of research that is concerned with viewing patient's veins accurately. It avoids multiple needle pricks and makes the veni-puncture process less traumatizing to the patient. The research deals with study of existing vein detection technologies and the development of a prototype based on the insights obtained from the study. The prototype was evaluated by experts paving way for a product that is effective and affordable for Indian scenarios.

INTRODUCTION

Vein detection is a novel and important area of research, the need to provide medical treatment without a time delay and in a less painful manner makes the research in this area significant. Difficulty in locating the veins leads to unnecessary needle penetrations causing blood clots, irritation, swelling, blackening of skin, etc. Vein detection is found to be useful in other potential applications like blood transfusion, blood donation, blood withdrawal and biometric security [1].

The existing methods used are:

- (i) **Manual procedures**, which includes usage of belts around bicep muscles, feeling the veins and usage of chemicals.
- (ii) **Ultrasound-guided procedures**, which uses ultrasound radiation on arms to find veins.
- (iii) **Secondary light sources**, where multiple high intensity light sources are used for viewing veins.
- (iv) **Red and near infra-red spectroscopy**, the visualization of the venous system by means of red and near infrared (NIR) spectroscopy [1].

Manual procedures are the conventionally used methods, but they are not suitable for children and are not effective on people with dark skin tone. Ultrasound-guided procedures involve expensive machinery and need additional training to the staff. Secondary light sources require a darkened room and might cause burns on skin. Among the existing

methods vein visualization by means of NIR spectroscopy is by far the most accurate and versatile method of vein detection.

The existing devices that are based on NIR spectroscopy, claim to solve difficulties in vein detection, but hardly few of them are being used in hospitals, primarily because of two reasons, the cost and portability issues. The need therefore arises to assess and quantify the pros and cons in existing devices and technologies used, and develop a low cost vein detection device which caters to the needs and constraints of Indian healthcare scenario.

The principle of vein detection using NIR spectroscopy is, when infra-red light is transmitted on palm it passes through tissue, which is absorbed by veins that have de-oxygenated blood. The veins appear darker than the surrounding tissue because of the absorbed radiations, which aids the medical fraternity to perform venipuncture in the first attempt.

Scope of the research is focused to affordability and improving the ease of product use. The learnings will be incorporated in developing a device which is robust in its core functionality of showing the veins that is otherwise not visible to the naked eye.

A comprehensive critical analysis is done on the products that exist in the market, later important parameters are evaluated for each of the product. The paper describes the design, development and initial evaluation of the product built.

LITERATURE REVIEW OF EXISTING PRODUCTS

Vein detection products have been in market for close to a decade now. These products can be broadly classified into two categories. Firstly, the products which have physical contact with the patient's arms and Secondly, non-contact type of products. The physical contact products are based on trans-illumination, which is a concept of using bright light on skin to illuminate the veins. These devices are of low cost and are widely implemented in hospitals. The drawback of these devices are, they have hygiene issues, as it involves a physical contact with the patient.

The non-contact detection devices use rather complex electronics and are extremely expensive. They are also usually bulky, making them less portable, for these reasons they are being implemented in fewer hospitals.

Apart from these categories of devices, there are others which subtly differ in their product features, five such devices have been chosen and reviewed, the conclusions of which have been used for making a design brief based on which the new device was developed.

Product 1:

Venoscope, is a trans-illumination based product. It is a product in market since 2011 and is a low cost vein locating device available in the market that has had considerable commercial success. It is sold at a price close to \$205 in U.S market, which makes it an affordable device in this product category of vein detection. The device can be effectively used on both adults and children which is supported by the FDA approvals.

The device is small and portable without any wires attached to it, making it extremely convenient for the nurses to use. The learning curve/cognitive load of the product usage is minimal on the user when

compared to the other products in the market. The product claims to be used in emergency situations, neo-natal care, Sclerotherapy, IV infiltrations, etc.

However, the product efficiency is decreased in well-lit ambient lighting conditions and works well only in dim/dark lighting conditions. The user is advised to use the product by reducing the ambient light conditions, which may be a cumbersome process to do for every patient. The device does not assure versatility of usage on obese and dark skinned patients which questions the usage of the product under real life situations that would involve all kinds of patients with different skin tones. The other big area where the product needs a makeover is the ergonomics, for instance, the handle of the product is box shaped with distinct edges and looks bulky. This may not be the most suitable shape and size for different percentile users. The aesthetics of the product are mediocre, the product form does not strongly convey the idea of being a healthcare device which is dependable, hygienic and robust.

Product 2:

Accuvein, is by far the most advanced type of vein detector device that has been developed till date. It has lot of features neatly packaged into a small hand-held device, and it overcomes the shortcomings of all the predecessors of similar vein detecting devices.

Starting with the product aesthetics, the device has the visual requirements of being a typical healthcare product, which the previous product Venoscope severely lacked. The biggest advantage of the device is that the vein detection can be done in normal ambient light conditions, although the user manual recommends adjustment in room lighting if necessary.

The device has features, like LCD screen - which shows usage details with brightness control and multi-language display options, speaker to give voice alerts of low battery, USB slot to transfer data, rechargeable battery, stand, temperature alarm, etc. The device is small in size

making it a feasible option to be used in mobile blood banks. The product also has stands as add-ons, for single person use.

The price of the product is the inhibiting factor, e-commerce websites quote the price to be as high as 2.5 Lakh rupees, which makes it a costly product to be used in small Indian hospitals. The statistics show that the device is being used only in 2000 hospitals worldwide, of which 1500 are in US alone, even though the product was launched nearly 5 years ago.

Product 3:

Phaneendra K. Yalavarthy, et. al.[3] have developed a device using a 4 LED setup that is incorporated on a clip on platform which can be attached to a mobile with camera for surface vein detection and imaging. The principle used in the product is, it utilizes the property of differential absorption of near infrared light by oxygenated and deoxygenated blood over normal tissue. The product has not yet been commercialized in the market, but the technique looks promising from the results shown in the paper, it claims to be an accurate and economical option that can suit Indian scenarios. The project bypasses usage of complex image processing techniques which lead to high costs involved in their implementation. The proposed system also might reduce the possibility of 'light spots' which lead to leak of energy, hence reduce efficiency. The product cost aimed is \$10 or lesser without the mobile phone, hence making the device affordable to medical practitioners.

The usage of product is straightforward and requires no prior specialized training or expertise, and can be implemented for various applications ranging from intravenous injection or blood drawing assistance, to mapping of surface veins.

From the results shown and discussed in the paper, we learnt that the detection of veins using this device is not exhaustive, but suggestive. The image quality depends on external variables like movement of

patients hand, ambient illumination and skin tone. In the present form the device looks bulky with the external batteries, which might make the device difficult to hold and use.

Product 4:

Master's thesis by **Askwini Kolar .et.al**, group of students from College of Engineering, Pune are developing a vein detecting device, using a beagle board and an infra-red camera. The product is stationery i.e. needs to be fixed in a place, the patient's hand needs to be placed in the device for vein detection and veni-puncture, this feature could hamper the feasibility of using the device in mobile blood bank centers, where portability is a very important criteria.

The device has many individual components, which increases the complexity, time taken to develop the product and cost of the device. The efficiency of the product reduces when used on dark skinned, hairy or obese patients, which has been a problem with most devices that were reviewed, except in the case of Accuvein.

Product 5:

Vein EZ is a hand-held device that is meant for infants. It uses a simple method of detecting the veins where only a high intensity red light source is placed under the skin. The device does not use any complex processors or image processing algorithms, which makes the product relatively low priced. Vein EZ is a product made for infants, thereby it is extremely small in size and light in weight.

The device has shortcomings, firstly, the target users are children – based on the product usage instructions, it seems like the child is expected to hold the device tightly in the wrist while being injected. This method of veni-puncture might not be feasible. The pictures shown in the website looks like device does not work well under normal ambient lighting conditions. The product usage is limited to viewing of veins in the wrist, but most of the veni-puncture happen in the forearm.

EVALUATION OF THE PRODUCTS

Products were evaluated on a scale of 0-10 points, the parameters considered are as follows:

Cost: The evaluation based on cost was done for each product based on which price range the product falls into and we evaluated how affordable the product is for the Indian scenarios.

Price Range	<10,000	<1,00,000	>1,00,000
Points	10	5	0

Hygiene factor: The products are broadly chosen as the one which touches the body, to show up the veins and the other is the non-contact device, which shows the veins by projecting an image back on the hand or on a portable screen.

Considering the hygiene issues, it is preferred to have a non-contact device, and the devices which have human contact need sterilization after every use.

The evaluation criteria for hygiene factors are as follows:

Criteria	Non-contact device	Contact device
Points	10	5

Effectiveness in ambient light conditions: One of the biggest challenges in detection of veins using infra-red based technologies is overcoming the loss of vein visualization quality.

This might happen mainly due to interference from ambient light sources like sunlight and electric bulbs. The external light sources make the veins appear as dull brown lines making vein visualization difficult. Based on the results of the product usage evaluation criteria has been set as:

Criteria	Works with ambient lighting	Veins are of suggestive quality	Veins are not visible
Points	10	5	0

Performance on challenging patients: Research proves vein detection is difficult to perform on the following kinds of patients:

- Obese patients
- Dark skinned patients
- Children
- Deep veined patients

Hence depending on how effectively the device works on these patients, an evaluation criteria has been set as:

Criteria	Works with ambient lighting	Veins are of suggestive quality	Veins are not visible
Points	10	5	0

Portability of the device: Portability plays an important role in ease of use of the product. The conditions under which the product could be used is diverse, for instance hospitals, blood banks, mobile blood camps, etc. In the evaluation criteria the devices which are wireless are given 10 points, whereas the devices which are stationery are given 5.

Criteria	Non-contact device	Contact device
Points	10	5

Evaluation table of the products:

	Venoscope	Accuvein	Yalavarthy	Kolar	Vein EZ
Cost	10	0	5	5	10
Hygiene	5	10	10	10	5
Light	5	5	0	5	No Data
Challenging Patients	5	5	0	5	0
Portability	10	10	10	5	10
Total	35	30	25	30	25/30

Inferences from Product evaluation:

Based on the parameters chosen and their corresponding points, all the products were evaluated. Product 1, Venoscope emerges as a winner, which is a trans-illumination based contact device. It is a low cost product which will be researched further with a scope of making a more effective product.

TECHNICAL INSIGHTS FROM REVIEW

Human eyes can detect visible light that is in the wavelength of 400 - 700nm of the entire electromagnetic spectrum. The special attributes of near-infrared wavelength which makes it suitable for vein detection are:

1. NIR can penetrate into biological tissue up to 3mm of depth.
2. The veins appear to be darker than the surrounding tissues as the reduced hemoglobin in venous blood absorbs more of the infrared radiation than the surrounding tissues.

In order to achieve penetration through the tissue and be able to clearly visualize the veins, the infra-red lighting should be performed under a tight optical window, which is 740 nm to 960 nm.

Naoya Tobisawa, et. al [1] proposes a system consisting of a high-intensity and low-leak light source, near-infrared CMOS camera and a small –one-eye head mounted display. Using the set up, they could obtain the trans-illumination images in all parts of the adult forearm, they could also obtain a clear image of deep-seated blood vessels [1], [2] the optical window needed for vein visualization is a window spanning 740 to 760nm. The experimental setup consists of 18 near infrared LEDs which have a radiation emission peak at 740nm and 5mm casing, which are placed in three concentric circles in the same focal plane.

The distribution of the LEDs are as follows:

- First circle uses 5 LEDs
- Second circle uses 6 LEDs
- Outermost circle uses 7 LEDs

A low cost web camera which has a CCD sensor array is used to acquire the vein images. The CCD alone is perfectly capable of detecting near infrared radiations up to a wavelength of 1mm but all modern cameras have an inbuilt infrared cutoff filter. The filter is placed in front of the sensor, thereby the web camera can see maximum amount of visible radiations. The procedure to visualize the veins in the infra-red region the filter needs to be removed and replaced with a custom made filter that is capable of blocking all the radiations which are below 720nm and allow only the NIR radiations to pass through.

The modified web camera is placed in the middle of the concentric distribution of LEDs, the radiations produced by this system is a constant source of light. In order to reduce the glare, and obtain even illumination, a diffusion filter is placed in front of the illumination system. Another problem that needs to be addressed is the specular reflexion observed at the skin surface. This problem can be solved by placing a polarizing filter, which would provide good contrast images with uniform lighting [2].

The device has a clip-on platform which is externally attached to the

mobile camera and the mobile phone display allows the user to view the veins. The clip on has an infra-red illumination system and a pass filter that blocks the visible light and allows the infra-red light to pass through. Through the inbuilt camera we can see the reflected infrared light at a required wavelength. The output image is seen as minor undulations on the surface of the skin which clarify the presence of the veins [3].

Photography involves usage of infra-red filters, this is possible because of the CCD sensors which are sensitive to infra-red wavelength and this is the reason why all CCD cameras have an in-built IR filter. In order to make a camera into an infra-red detecting camera, the in-built IR filter needs to be carefully removed. The camera also needs to have sufficiently high spatial resolution to be able to detect the vein details clearly [4].

BUILDING PROTOTYPES

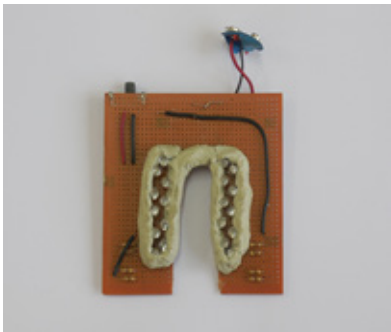
Based on the technical insights obtained from various research papers, many prototypes were built as a proofs of concept. These prototypes were tested for their feasibility in various lighting conditions and on various kinds of users, following are the iterations involved in the prototype building process:

ITERATION 1

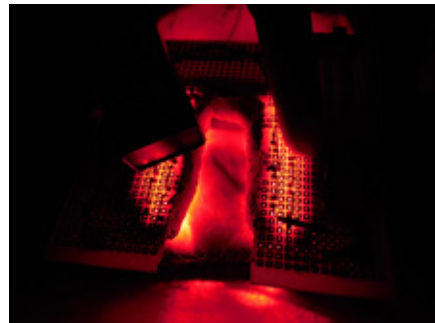
In this first prototype 20 red LEDs were used. The wavelength of them were 650nm, the prototype was in the form of tuning fork with space in the center for viewing veins.

The prototype highlights the already visible superficial veins and it's not effective in cases of challenging users like deep veined, obese, dark skinned and children. The device is slightly more efficient when the tests are done in darkness, where the veins appear to be darker.

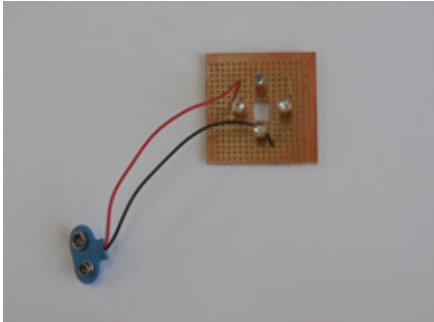
Prototype



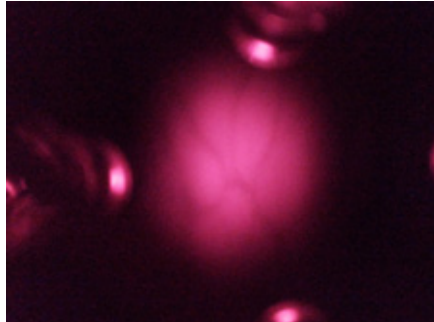
Result



Prototype



Result



ITERATION 2

Based on the results obtained from Iteration 1, we decided to use a different type of LED. The aim of making a new circuit was to reduce the number of LEDs being used and make a more compact device. In this prototype a non-contact device was made and tested, where 4 LEDs were attached to the mobile phone [3].

The device performance is similar to Iteration 1, where the device is ineffective in producing good clarity vein images under bright ambient conditions. The analysis of results we thought that a possible reason could be the wrong usage of IR wavelength. This led to further iterations in different wavelengths.

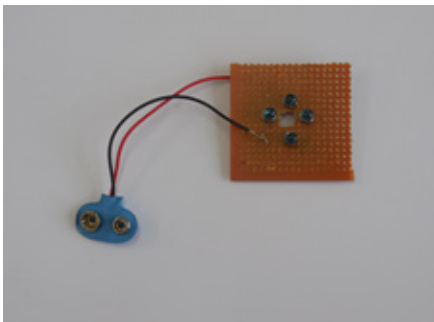
ITERATION 3

The third iteration, LEDs with specific wavelength of 750nm were procured and tested in a setup very similar to Iteration 2, the results in this setup were slightly better. Analysis of the output images proved that the camera that was in the mobile phone had a partial infra-red block filter which was interfering with the quality of veins viewed.

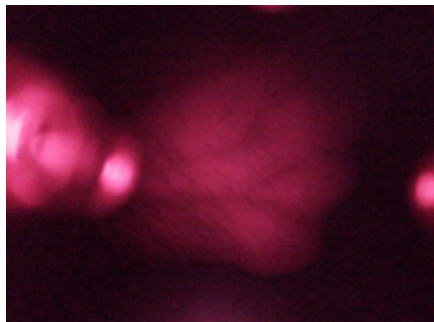
Non-contact prototypes tested in iterations 2 and 3 did not give good quality images with a mobile phone camera in bright ambient light conditions. This could be improved if image processing is done on the output images. The mobile phone camera being used needs to have its infra-red filter removed and replaced with a better infra-red pass filter which completely blocks visible light and allows only the infra-red wavelength to pass through.

The approach of having a non-contact device setup has the desirable property of being hygienic, but it increases the system complexity and cost – which contradicts the goal of having an efficient and low cost vein viewing device.

Prototype



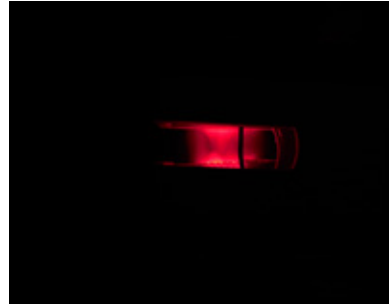
Result



Prototype



Result



ITERATION 4

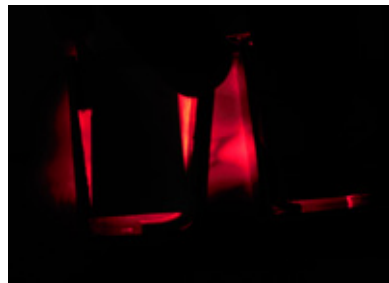
Based on the inferences obtained in previous iterations, we decided to further explore the contact devices with different LED wavelengths and circuit configurations. Red colored LEDs with higher intensity were used in the prototype along with an enclosure to avoid the leakage of ambient light into the vein viewing area. The results were satisfactory as the veins viewed were more distinct and darker than the previous prototypes.

The increase in the LED output intensity and having an enclosure to avoid the leakage of ambient light improved the output results, but the rigid enclosure made the vein viewing difficult in places where there were bends/uneven skin surfaces like the elbows.

Prototype



Result



ITERATION 5

In the iteration 5, a flexible device enclosure was made to facilitate vein viewing. The flexibility helped vein viewing in places with bends and uneven surfaces. The number of LEDs used were increased to 6 from 2, to improve the intensity and clarity of vein visualization.

The flexible enclosure and increase in intensity improved the quality of vein visualization, but the leakage of light though the enclosure reduced the effectiveness of dark veins being visible in ambient light conditions.

Prototype



Result



ITERATION 6

A 3d printed enclosure with 6 closely placed LEDs was used in this iteration. The objective of the prototype was to make a device with high intensity and less leakage of light. The results obtained with the device was by far the most effective and worked well in ambient light conditions and on various kinds of challenging users. The device was considered as

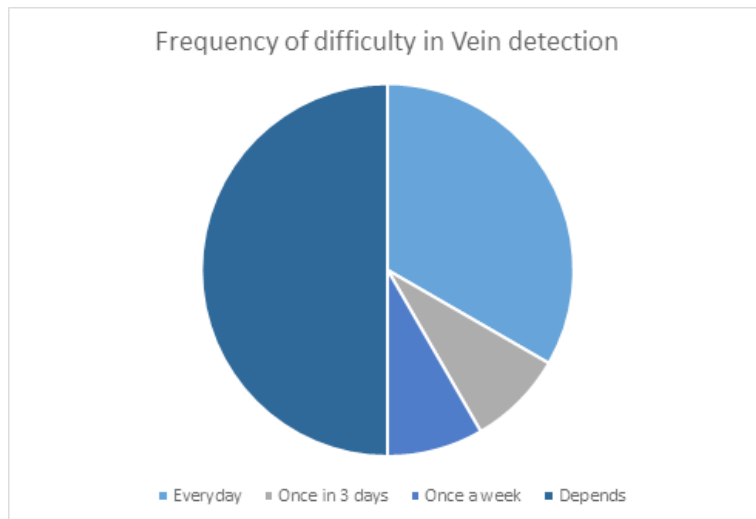
the final prototype for evaluation with doctors, nurses and patients.

EVALUATION OF THE PROTOTYPE

The objective of the survey was to find the need for a product that would help the medical fraternity locate the veins, the awareness levels the doctors and nurses have about using an electronic device for vein viewing, the price a hospital could afford for a vein detecting device and suggestion for improvement from the doctors and nurses about the prototype.

Details of the survey:

<i>People interviewed:</i>	12, Doctors = 5, Nurses = 7
<i>Hospital Type:</i>	Government hospital : 1 Private Hospital : 2 Blood Banks : 1
<i>Average age of Users:</i>	32.75 Years
<i>Average experience of the Users:</i>	7.8 Years



INFERENCES FROM THE SURVEY

Of the 12 people surveyed, all agreed that there were instances when it was difficult to spot the veins especially amongst the challenging patients. There were no clear data on how often they faced difficulties in spotting the veins, due to lack of statistics.

The various preferred methods used to spot the correct vein are :

1. Feel the veins with fingers
2. Using Traction belts
3. Usage of electronic gadgets
4. Trial and error

From the survey we learnt that every venipuncture process involves usage of a traction belt and pressing/feeling of veins. For cases when

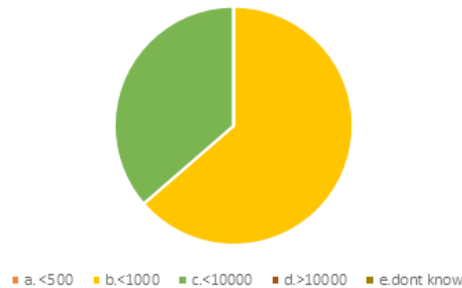
Acceptance of an electronic device for vein finding



difficulty in spotting veins persists even after usage of traction belt, trial and error process is followed, where multiple veni-punctures are administered leading to pain and trauma to the patients. An interesting insight that was got in the blood banks -- on occasions where there was difficulty in spotting veins, usually the blood donors are rejected to avoid causing pain to the donor, this leads to reduction in the amount of blood collected in donation camps.

The acceptance level of using an electronic device to spot veins was encouraging. Most of the people interviewed were eager to use technology which could reduce the human errors involved in venipuncture.

Affordability for a vein detector device



Many of the government hospitals and blood banks prefer to have a low cost vein detection device, which is in the price range of less than 5000 rupees. This makes the trans-illumination method of vein viewing the most suitable choice, as non-contact devices are more expensive.

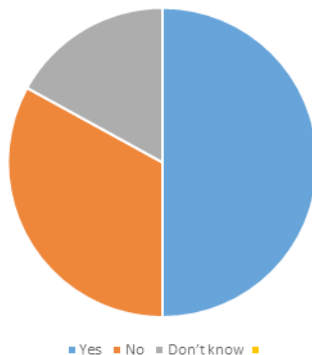
The awareness about vein viewing technology was minimal amongst the medical fraternity. Usually nurses in blood banks were aware of the technology and some of them had used vein viewing devices.

The next part of the survey involved a demonstration on how to use the product. The prototype was then tested by the doctors and nurses to validate its effectiveness, the inferences obtained about the product were:

The prototype showed veins on the forearms of the people on whom it was tested, under ambient light conditions. More detailed study needs to be done on a larger user base for concrete statistics about the versatility of the prototype.

The learning curve involved in the product usage had to be kept minimal. The process of using the device and performing venipuncture must not be an additional tedious process for the user when compared

Does the device need sterilization ?



to the conventional procedure.

Trans-illumination devices touch the patient's hand during vein visualization, this lead to hygiene issues. When asked about the consequences of having a device which would touch a patient -- doctors and nurses had remarks and suggestions. Few doctors suggested sterilizing the patients hand instead of sterilizing the device.

CONCLUSIONS

A comprehensive study was made on an assortment of vein detection devices, by which the pros and cons of each devices were thoroughly understood. From the inferences got by the study, a prototype was developed and tested. The current limitation of the concept is that the device is based on the principal of trans-illumination, due to which the device needs human contact for efficient working, this leads to hygiene issues.

The other challenges faced in building the device were obtaining the tight optical window which makes the veins visible. The optical window can only be achieved by using the correct wavelength and making the ambient light void of any sunlight to eradicate unwanted interferences in vein visualization. The device needs to be affordable, accurate and low power consuming device to increase the user audience.

Suggestions for improvement:

To have space for injecting the needle while using the device for vein detection.

To reduce the brightness of the LEDs as the respondents found them to be extremely bright and interfering with the vein view area.

To have an arrangement which would help the nurse insert the injection without having to hold the device.

Future Scope of the project:

- To make an ergonomic body that provides good grip and comfort to the user, with minimal cognitive load.
- To in-corporate an option for performing venipuncture during the vein detection process.
- Have a multi-step lighting of LEDs, to make the vein visualization convenient at different ambient lighting conditions.
- To have an appealing and robust form factor which withstands daily use.
- Perform a comprehensive study of the device on various kinds of patients and evaluate the product's performance.
- Explore possibilities of having a non-contact device, which is currently obstructed due to the high costs involved.

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