Utility of infrared imaging of lower extremity subcutaneous venous structures

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Background

Venous disease affects one in three people in the United States. Subcutaneous varicosities are a prominent feature of the disease condition. Patients with untreated disease, those who have undergone Radio Frequency Ablation or other procedures have residual varicose veins at varying depths. These varicosities do lead to pooling of blood and significant symptoms typically with aches and swelling. Patients who have undergone sclerotherapy for these veins often recall a marked relief in their symptoms. At the same time there are people with no significant underlying venous reflux disease with 'spider veins'. Such veins would be considered to be cosmetic as there is no underlying reflux and there are no other concurrent symptoms. The current method of assessing the subcutaneous veins is limited to visual inspection under visible light. We explore and establish the utility of infrared imaging in the quantification of subcutaneous varicosities.

Properties of Infrared Light

Infrared light penetrates just below the skin. It is ambient in sunlight. Hemoglobin in blood absorbs infrared light. Thus taking an infrared image of a patient extremity shows the sub-cutaneous veins as dark lines against a pale skin. Infrared imaging does not add any risk to the patient as images are taken in ambient infrared light.

Objective

To develop a method to better characterize venous disease amongst patients who present for sclerotherapy or phlebectomy.
Utilize the property of sub-cutaneous penetration of infrared light and the absorption spectrum of hemoglobin to produce superior images of veins. To analyze the images using semi-quantitative method of assessing severity as laid out by the IVSS score.

Methods

We utilized a case comparison study conducted since 2013.
Sixteen patients presenting to the venous clinic for sclerotherapy or phelebectomy were studied in an ambulatory setting. Images were taken utilizing visible and infrared light. Ambient light form common light sources was utilized thus there was no increased risk to patients. Informed consent for photography was obtained. Identical images with visible and infrared light were utilzed for analysis. Identical images in the infrared and visible spectra were obtained by the photographer. The lighting, distance to the camera and patient position was standardized. Photographs were taken with a camera modified to image in the infrared spectrum. Visible light images were obtained with a separate camera or using a special filter that allowed infra-red and blue visible light.

Data Analysis

Varicose veins were characterized as mild, moderate or severe using the IVSS method of visual estimation. Images from the visible spectra and infrared spectra were analyzed independently. The investigator was blinded to patient identity and viewed the images in no particular order. Data was collected by image number and tabulated. The null hypothesis implied there would be no change in severity of venous disease as assessed by infrared imaging.

IVSS classification criteria were used on either image to give a score:
0 for no veins, 1 for mild, 2 for moderate and 3 for severe

Patient #	Visible Light	Infared	Change
001	2	3	1
002	1	3	2
003	2	3	1
004	3	3	0
005	1	1	0
006	2	3	1
007	3	3	0
008	0	3	3
009	2	2	0
010	1	2	1
011	3	2	-1
012	1	1	0
013	2	2	0
014	2	3	1
015	3	3	0
016	3	3	0

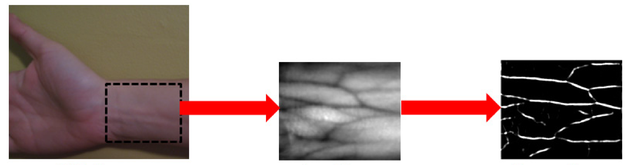
Patient #001

Patient #002

Patient #003

Results

Analysis of data from 16 patients is shown in the table. 68.8% (95% confidence interval (CI) 44-86%) of images were categorized as moderate to severe venous disease using visible light as opposed to 87.5% (CI 62.7-97.8%) using infrared light. When analysis was restricted to severe venous disease alone the results were a striking 31.3% (CI 13.9-55.9%) for visible light as opposed to 62.6% (CI 38.5-81.6%) for infrared light.
Visualizing veins using infrared light is superior to visual inspection under visible light. Infrared light is ambient, safe, ubiquitous and the imaging equipment utilized is easily available. These techniques are easy to reproduce and adopt widely. The utility of this technique in clinical practice warrants further investigation.
We are currently working on the optimisation on the vein map extraction. Our objective is to extract the binary image of the vein network beneath the skin where 1 refers to a vein and 0 to the background or skin. The figure below shows an example of our recent investigation in this topic.



Visible image — Infrared image — Binary vein map

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