

EXPLORATION OF A LOW-COST VEIN MAPPING DEVICE USING NIR WAVELENGTHS AND THE HESSIAN-FRANGI FILTER

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ABSTRACT

Venipuncture procedures are one of the most common minimally invasive clinical procedures, however, the success of vascular access can vary, depending on the patient's age, quality of veins, thickness of tissue, and the experience and technique of the clinician performing venipuncture. Failure to access veins on the first try, followed by repeated attempts can result in increased risk of infection, patient discomfort, hematoma, and prolonged procedure time. Current vein detecting devices can be very costly or require contact with the patient, which could expose the clinician to patient blood. A safe, low-cost, and easy-to-use vein detection device can simplify venipunctures and help to reduce procedural risks to both patients and clinicians. In this study, a vein detection imaging system using red light and near-infrared (NIR) light, with wavelengths of 625 nm, 850 nm, and 940 nm, was developed using common off-the-shelf components. The system uses light-emitting diodes (LEDs) as excitation sources to highlight subcutaneous vein pathways, capture this vein map, and save the image to a local repository. An image processing algorithm was developed in MATLAB to produce an output using a 2D Hessian-Frangi Filter (HFF) and evaluate the accuracy of vein detection. The prototype system can successfully extract dorsal vein features in the hand. This technology can lower the barriers to provide safer care, specifically in resource-restricted environments. The future of HFF in clinical settings for venipuncture can lead to image-assisted procedures using off-the-shelf components, lowering the cost of image-assisted venipuncture procedures, and reducing the risk of repeated needlesticks.

Keywords: non-ionizing radiation, venipuncture, near-infrared, Hessian-Frangi, dorsal vein, vascular access, needlestick

INTRODUCTION

Venipuncture procedures are one of the most common minimally invasive clinical procedures that are being performed today, and it can benefit from point-of-care imaging that assists clinicians in navigating patient vasculature. Venipuncture procedures are included in medical treatments that involve accessing veins, such as delivery of medications and fluids or blood sampling. About 90% of hospitalized patients require cannulation, resulting in over one billion venipuncture procedures annually [1, 2]. The success of vascular access can vary, depending on the depth of the vein of interest and the experience and technique of the clinician performing venipuncture. Failure to access veins on the first try, followed by repeated attempts can result in increased risk of needlestick injuries, infection, patient discomfort, hematoma, and prolonged procedure time [3]. Current vein detecting devices, such as ultrasounds, can be very costly and some devices require contact with the patient, which could expose the user to patient blood. A safe, low-cost, and easy-to-use vein detection device can help to reduce the risks to both patients and clinicians by simplifying venipuncture procedures.

Near-infrared (NIR) radiation between 700nm and 1000nm can penetrate under the skin [4-7]. When exposure is limited, NIR in the non-ionizing range does not pose as high of a risk of radiation as ionizing wavelengths, such as in X-rays [8]. NIR light has been previously used to visualize subcutaneous vascular structures, as the hemoglobin in blood is able to absorb light in this range [1, 2, 7]. As light penetrates through tissue, light is absorbed, scattered, and reflected. The backscattering of light can be captured using a photosensor [4-6]. Since veins and surrounding tissue absorb and reflect different wavelengths of light, a sensor will be able to differentiate between dark veins and lighter tissue. While NIR light is limited in the depths it can penetrate under the skin, it can be useful to visualize veins that are regularly accessed for venipuncture. Previous research and experiments demonstrate the feasibility of using NIR light [4, 5] to assist clinicians in identifying and visualizing veins with greater confidence and reliability than traditional methods [9].