Jan Dreyer*, Katharina Huenges, Jochen Cremer and Assad Haneya

A new device for vein localization and effect of application of disinfectant spray on its efficiency

Abstract: A functional device was developed to immediately show the localization of veins by detecting a temperature increase on the skin directly above them. Our new idea, compared to other developments, is the comparison of temperatures between a small, ideally punctiform, skin area, and a larger circularly surrounding area. This is realized by two infrared temperature sensors, one with a small field of view, and the other one with a larger field of view. The position of the vein is indicated by two laser modules, which beams cross in one spot, when the device is held in a defined distance to the skin. If the device is held over a vein, the laser spot lightens up. The device was tested in ten study participants. Cooling of the skin by disinfectant spray prior to the measurements increases the temperature gradient and thereby improves the efficiency of the device. Temperature profiles of four skin areas of each study participant were measured before and one minute after application of disinfectant spray. After application of disinfectant spray, a temperature difference of more than 0.3 K between a measuring point above a vein and points 15 mm next to this could be found in 36 out of 40 measurements (90%), compared to 26 out of 40 (65%) before disinfection. The mean temperature gradient could be increased from 0.476 K to 1.03 K ($p < 0.001$).

Keywords: vein finding, infrared thermography, temperature gradient, disinfectant spray, MLX90614, Arduino

https://doi.org/10.1515/cdbme-2017-0026

***Corresponding author: Jan Dreyer:** Department of Cardiovascular Surgery, UKSH Kiel, Germany, Arnold-Heller Str. 3, 24105 Kiel, Germany, e-mail: jan.dreyer@uksh.de
Katharina Huenges, Jochen Cremer and Assad Haneya: Cardiovascular Surgery, UKSH Kiel, Germany, Arnold-Heller Str. 3, 24105 Kiel, Germany, e-mail: katharina.huenges@uksh.de, jochen.cremer@uksh.de, assad.haneya@uksh.de

1 Introduction

Puncture of peripheral veins is frequently performed in everyday clinical routine. For patients and medical staff this may often mean a stress and painful procedure.

One method to localize superficial veins is visualizing the temperature gradient on the skin above blood vessels due to the higher temperature of blood vessels compared to the surrounding tissue.

Several theoretical and experimental studies have been published on this subject. First detailed analyses of temperature distributions on the skin surface were made by Torell and Nilsson in the 1970s [1]. In 2007 Wu et al. give a detailed description of the simulation of temperature increase on the skin by a subcutaneous heat source [2]. Their calculations suggest an increase of the skin temperature over subcutaneous veins depending on diameter and depth of the heat source.

These temperature gradients can well be measured contactless by infrared temperature sensors. In the past, some devices and applications have already been developed based on this effect [3]-8].

It was our ambition to develop a functional and easy to handle device, which could immediately show the examiner the correct localization to perform venipuncture.

The new idea compared to other developments is the comparison of temperatures between a small skin area, ideally punctiform, and a larger area circularly surrounding the small area. This is realized by two infrared temperature sensors, one with a small field of view, the other one with a larger field of view, which must be positioned in a defined distance from the skin (see **Figure 1**).

The device is manually moved perpendicular to the skin by the examiner, while two laser modules, which beams cross in the predefined distance, show the center of measurements. The intensity of the light spot depends on the measured temperature difference. When the examiner crosses a superficial vein the light spot brightens.

During our first self-experiments we found, that cooling the skin by disinfectant spray prior to measurements

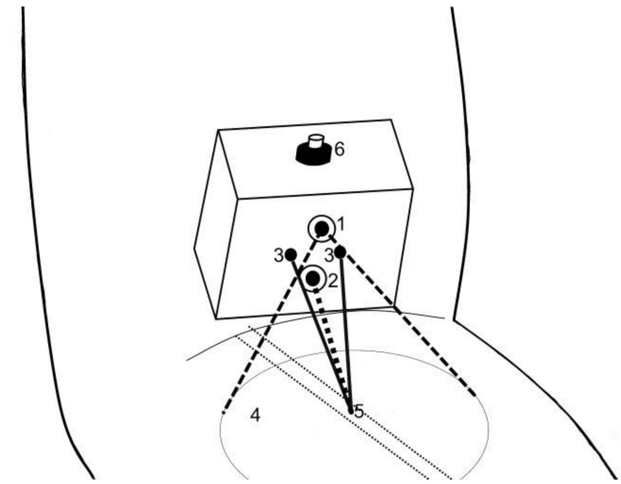

Figure 1: New device for vein localization (1: Infrared Sensor with larger Field of View; 2: Infrared Sensor with smaller Field of View; 3: Laser modules; 4: Measuring area of 1; 5: Measuring point of 2; 6: On-/Off-Switch [9]

increases the temperature gradient and thereby improves efficiency of the device. Our intention was to verify and quantify the effect on the temperature gradients by cooling the skin with disinfection spray in an experimental trial.

2 Methods

2.1 The device

Basis of the prototype, which at the same time is the measuring device for the experimental trial, is an Arduino MICRO (Arduino Srl, Scarmagno, Italy). Temperature measurements are performed by infrared thermopile sensors. Via the digital input/output pins of the Arduino MICRO two digital infrared temperature sensors type MLX90614 (Melexis N.V., Ypern, Belgium) are controlled.

One sensor has a small field of view, in this case 5°. In a defined distance of 45 mm that means, the field of view covers an area 3.9 mm in diameter. The other temperature sensor has a 35° field of view. In the same distance to the skin its field of view covers an area of 38.4 mm in diameter.

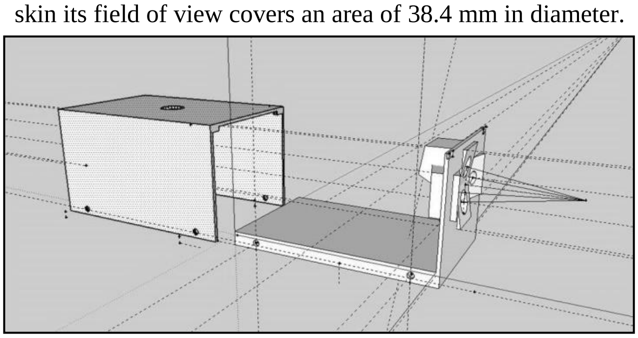

Figure 2: CAD Design

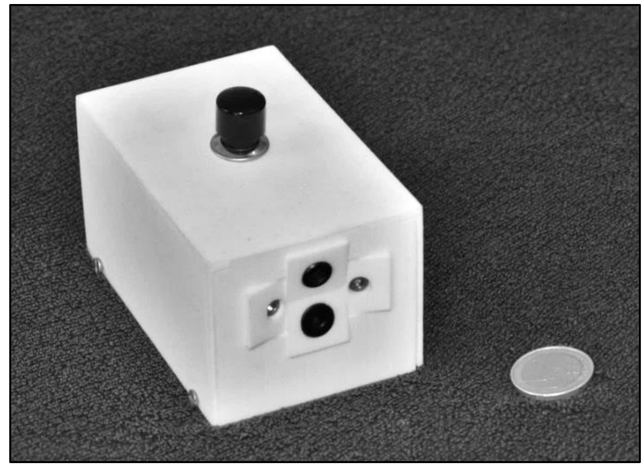

Figure 3: Prototype and measuring device

Two laser modules are aligned next to the two sensors. Their beams cross in a distance of 45 mm in the middle of the measuring areas of sensor 1 and 2.

The case of our prototype was constructed via computer aided design (see **Figure 2**) and 3D printed by Shapeways Inc. (New York City) out of the material „Strong & Flexible Plastic“ (see **Figure 3**).

While manually changing the position of the device, the examiner has to make sure the laser beams cross in one spot on the skin to keep the correct distance. At the same time, it is necessary to hold the device orthogonal to the skin surface, so that the measuring areas are aligned correctly.

Temperatures are processed by the Arduino MICRO. When a defined temperature difference between the two sensors is exceeded, the intensity of the laser beams is enhanced depending on the size of temperature difference.

2.2 Data collection

In order to get first applicable data, the device was tested in a group of ten study participants.

To generate data, we used our prototype as measuring device. Measuring spots were marked on cubital fossa and radial forearm of study participants in a distance of 2.5 mm (see **Figure 4**).

For data collection, the device was reprogrammed to sequentially send mean values of twenty measurements into an Excel sheet via USB. The examiner starts measuring on the first mark. Within one second the first measurements are processed. After this the laser spot blinks six times, which gives the examiner time to aim at the next measuring point.

Continuing this way temperature profiles are created for each measuring area. The same procedure is repeated one minute after application of disinfectant spray.

Figure 4: Measuring spots marked on a forearm

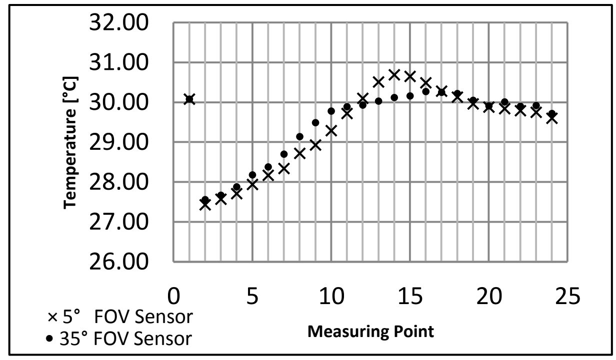

Figure 5: Temperature profile of the cubital fossa after application of disinfectant spray

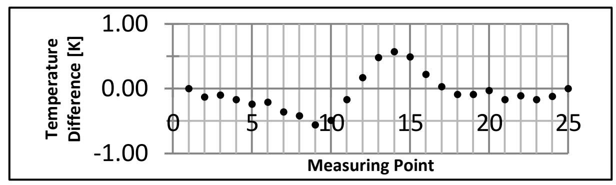

Figure 6: Temperature difference between the two sensors in the measurement of Figure 5

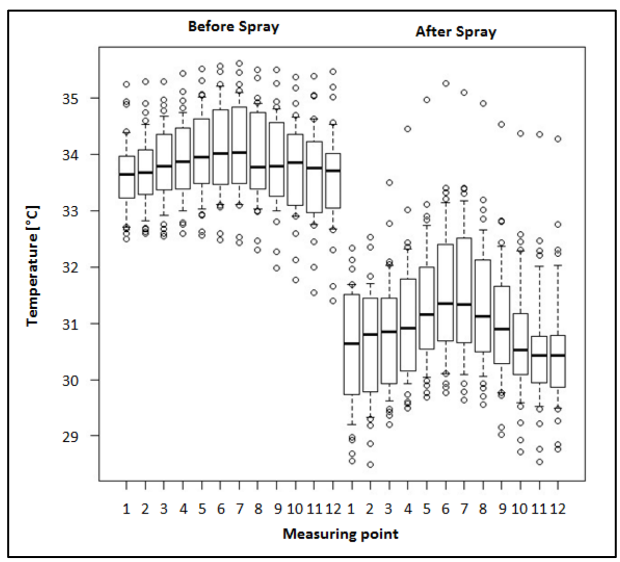

Figure 7: Summary of all temperature profiles 30 mm around veins

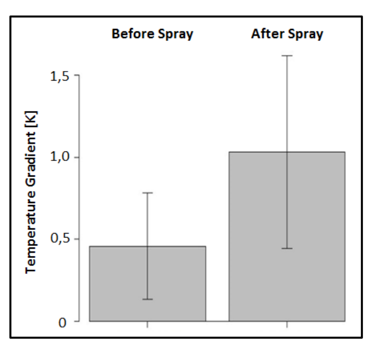

Figure 8: Difference in temperature gradients before and after application of disinfectant spray

Afterwards the measuring areas are examined using ultrasound. The positions of superficial veins in the ultrasound pictures are determined.

For further analysis maxima in temperature differences between the sensors are identified in the temperature profiles. The localizations of these maxima in the temperature profiles are compared to the positions of the veins in the ultrasound picture.

For the statistical analyses temperature values over a distance of 30 mm around each maximum are selected.

The temperature gradients between the temperature directly over a vein and the temperatures 15 mm next to this are calculated in each profile, where a vein is detected.

3 Results

Five female and five male study participants were examined.

In three of 40 measuring areas no clear maximum in the temperature differences between the two sensors could be identified.

An exemplary measurement is shown in **Figure 5** and **Figure 6**. A summary of all temperature profiles in 30 mm areas around veins is shown in **Figure 7,** separated in measurements before and measurements one minute after application of disinfectant spray.

The mean gradient between the temperature directly above a vein and the corresponding temperature 15 mm besides was 0.46 K before application of disinfectant spray, whereas the mean gradient afterwards was significantly higher with 1.03 K ($p = 4.35e-07$) (**see Figure 8**).

Before application of disinfectant spray in 26 out of 40 measurements (65%) the calculated temperature gradient was greater than 0.3 K. After application of disinfectant spray in 36 out of 40 measurements (90%) a gradient of more than 0.3 K was found.

4 Discussion

As shown in the exemplary measurement the comparison of temperatures measured by sensors with different FOVs can indicate the localization of a vein.

Figure 9: Latest version of the prototype

An overall positive effect of application of disinfectant spray on temperature gradients could clearly be seen overall.

If the temperature threshold for detection of a superficial vein is set as 0.3 K the detection rate in the analysed profiles could be raised from 65% to 90%. The calculated temperature gradients could be significantly increased by 0.58 K.

This shows that cooling the skin by application of disinfectant spray is a useful procedure before using this new device, as disinfection usually is performed prior to vein puncture anyway.

Our results are in accordance with the findings of Villaseñor-Mora et al. who showed a contrast enhancement of subcutaneous veins in infrared pictures by application of sun blocker on the skin [9].

Since our prototype has not been used in clinical practice yet, the impact on clinical routine may only be estimated. We aim to improve certainty in vein puncturing especially for beginners in future.

There might also be other possible clinical applications like placement of a central vascular access or localization of vein grafts (for example the great saphenous vein) in coronary artery bypass surgery.

The latest version of our device is now operated by an ATtiny45 microchip on a printed circuit board which makes the device significantly smaller. Next steps will be even more miniaturization and clinical trials.

Author's Statement

Research funding: The authors state no funding involved. Conflict of interest: Authors state no conflict of interest. Informed consent: Informed consent has been obtained from all individuals included in this study. Ethical approval: The research related to human use complies with all the relevant national regulations, institutional policies and was performed in accordance with the tenets of the Helsinki Declaration, and has been approved by the authors' institutional review board or equivalent committee.

References

[1] Torell LM, Nilsson SK. Calculation of skin temperature increase caused by subcutaneous veins perpendicular to the skin surface. Physics in Medicine and Biology 1980; 25: 85-91.
[2] Wu Z et al. A basic step toward understanding skin surface temperature distributions caused by internal heat sources. Physics in Medicine and Biolog 2007, 52: 5379-5392.
[3] Cohen RF, Tumey DM. Systems and methods for locating a blood vessel. Patent 2008: WO 2008/143741 A1.
[4] Pennypacker C. Infrared imager for viewing subcutaneous location of vascular structures and method of use. Patent 1989: US 4817622.
[5] Nosari ER. Method of locating vein. Patent 1976: US 3998210.
[6] Esparza J, Bahuguna RD, Williams GT. Infrared aided method and apparatus for venous examination. Patent 1997: US 5608210
[7] O'Connell P, Method of locating and marking veins. Patent 1997: US 5678555.
[8] Shalom M, Ghilai S, Weizer A. Instrument and method for locating and marking a hot spot in a person's body tissue. Patent 2002: US 6464646.
[9] Dreyer J. Vorrichtung zur berührungslosen Lokalisierung warmer Bereiche auf einer Fläche. Patent 2011: DE102011121020 B3.
[10] Villaseñor-Mora C, Sanchez-Marin FJ, Garay-Sevilla ME. Contrast enhancement of mid and far infrared images of subcutaneous veins. Infrared Physics and Technology 2008; 51:221-228.