The hand held Doppler device for the detection of perforators in reconstructive surgery: What you hear is not always what you get

Carlijn M. Stekelenburg
Pia M.D.G. Sonneveld
Mark-Bram Bouman
Martijn B.A. van der Wal
Dirk L. Knol
Henrica C.W. de Vet
Paul P.M. van Zuijlen

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Abstract

Introduction: Perforator-based flaps have become indispensable in the treatment of burn scars. Preoperative perforator mapping is often performed by use of the hand held Doppler device, partly due to its convenience and the low costs. We expected to find sufficient evidence in literature to support the use of the device, however available literature showed a distinct lack of clinimetric studies that adequately tested the reliability.

Materials and Methods: To assess reliability, perforator locations were mapped independently by two clinicians using an 8MHz Doppler device. In healthy volunteers the elbow region or the peri-umbilical region were randomly chosen to be the measurement areas of predefined squares (7x7 cm). Subsequently, the perforators within the area were mapped with Duplex to establish the validity by means of the positive predictive value.

Results: 20 volunteers were included. The hand held Doppler technique showed moderate reliability with a mean Dice coefficient of 0.56. Also, poor validity was found expressed by a mean positive predictive value of 55%.

Conclusions: Surprisingly, this study has shown that the performances of the hand held Doppler device were moderate. The Doppler should not be used solitary for the detection of perforators.

Introduction

Scar contractures are frequently observed following extensive burn wounds. The use of perforator-based flaps in reconstructive (burn) surgery has increased significantly and has been established as a safe procedure1-6. Because perforators are distributed throughout the body, viable flaps can be raised from a great variety of anatomical locations7. The exact locations of perforators however, vary significantly between individuals. Preoperative perforator mapping facilitates flap harvesting and saves operating time.

In the past many years, several advanced diagnostic tools have become available, such as Magnetic Resonance Imaging (MRI), Computed Tomography Angiography (CTA), Digital Substraction Angiography and Color Doppler Sonography (Duplex)8. These techniques have proven to accurately detect perforator locations. They are however time consuming, cannot be performed during operation and most of these techniques are invasive and expensive. Furthermore, they have difficulty marking the exact location of identified perforators on the skin. A less modern device, the hand held Doppler, is on the other hand portable, inexpensive, easy to perform and interpret, and can be used during surgery by the surgeon. Furthermore, it has gained an important place as diagnostic tool in the upcoming field of perforator flaps because of its flexibility and readily available character1,2,4-6,9.

The hand held Doppler device should be reliable and valid for application in clinical practice. When two clinicians use the same Doppler device they should be able to trace the same perforators. We expected to find sufficient evidence to support the use of the hand held Doppler device, however, available literature showed a distinct lack of clinimetric studies that adequately tested reliability. So far the Doppler device has only been studied for its validity, which means that a positive signal indicates the presence of a perforator10-17. The presented validity properties of the Doppler device differ considerably across studies10-17. Therefore, the aim of this study was to 1) test the reliability of the Doppler device for locating perforators 2) assess the validity of Doppler as a diagnostic tool for detecting perforators.
Materials and Methods

Subjects
Healthy volunteers participated in the study. The general principles outlined in the Declaration of Helsinki were followed. Participants were randomly assigned to two different groups based on the location in which perforators were mapped: elbow crease or the periumbilical region. Allocation concealment was carried out using sequentially numbered, opaque sealed envelopes. The sequence was determined by shuffling the envelopes by a researcher. The elbow crease was chosen because it is one of the areas prone to burn scar contractures, which are commonly released by means of perforator-based flaps. The periumbilical region was chosen because this is a well-established location for perforator-based flaps, such as the deep inferior epigastric perforator (DIEP) flap. Each participant was positioned supine, with both arms resting alongside the body and the palms facing down. An area of 7x7 cm was marked using a plastic mould and a black permanent marker. To standardize the locations on the elbow or the abdomen, anatomical landmarks (the belly button and midline of the elbow crease, respectively) were used.

Hand held Doppler device
A Huntleigh Dopplex D900 (Cardiff, UK) with an EZ8 8MHz probe and Parker Aquasonic 100 ultrasound transmission gel was used. The hand held Doppler device will be referred to as Doppler in this study. When a positive signal was located, the probe was moved in all directions to ensure that the signal did not continue in any direction; indicating an axial vessel instead of a perforator. Each perforator location was marked with a permanent marker, on a transparent sheet that was laid on top of the previously marked area on the skin (Figure 1). This procedure ensured blinding of the observers.

Color Doppler sonography (Duplex)
To assess the validity, Color Doppler sonography (iU22 Duplex with a L17-5 transducer, Philips, Eindhoven, The Netherlands) was used as standard for comparison, which has been successfully used to preoperatively assess flaps for reconstructions in the head and neck, trunk and extremities. The same vascular laboratory technician mapped the perforators within the same squares described. These perforator locations were traced onto another transparent sheet using the permanent marker.

Measurement procedure
Two clinicians mapped the perforator locations within the squares on the participants. Both clinicians were plastic surgeons with extensive experience using the Doppler device for the detection of perforators. The locations were marked on transparent sheets and compared to assess the reliability through the agreement between the detected locations. Markings within 1 cm radius were considered to correspond to the same perforator location. Duplex was performed directly following the Doppler procedure (with a maximum of 1 hour in between) by a vascular laboratory technician to check if a perforator was present at a location that was found by Doppler. During all repetitive measurements the participants remained in the same position and room temperature was kept constant.

Statistical analysis
Reliability
The interobserver reliability was calculated based on the two measurements of two clinicians. The positive agreement was quantified (both clinicians detected a perforator on a specific location), by use of the Dice coefficient (DC): $\text{Dice} = \frac{2 \times n_{AB}}{n_{A} + n_{B}}$, where $n_{A}$ and $n_{B}$ are the number of locations found by the two observers and $n_{AB}$ is the number of perforator locations shared by the two observers. The Dice coefficient (DC) is also known as the proportion specific positive agreement. This coefficient is the best parameter to express the agreement in this study, because it equals 1 if A and B find exclusively shared locations. When A and B find perforator locations that are not found by the other observer it is smaller than 1 and the coefficient equals zero if none of the locations found by A and B correspond. For each volunteer the DC was calculated based on the number

![Figure 1. Example of the performance of Doppler mapping. The transparent sheet is lifted when mapping is performed and replaced on the skin to mark the locations with a permanent marker.](image)
of corresponding perforator locations per volunteer. These DC’s were bootstrapped with replacement of 10,000 times. The average of the 10,000 mean DC’s was calculated and from this, the bias corrected accelerated (BCa) 95% confidence interval was calculated.

**Validity**

To analyze the validity of the Doppler as a diagnostic device, the locations of the perforators found by Doppler were compared with the locations found with Duplex using the positive predictive value. Of the positive Doppler perforator locations that were not confirmed with Duplex (false positives), it was registered if it concerned the presence of an axial or intramuscular vessel or not. These features are important in clinical practice because both vessels are not suitable to base a perforator-based flap upon.

**Results**

**Participant characteristics**

A total of 20 participants (1 male and 19 female) were enrolled in this study. The mean age was 44.2 (SD 14.1) years and the mean Body Mass Index (BMI) was 25.7 kg/m² (SD 4.1). Four participants were smokers. Eleven participants were randomly assigned to the ‘elbow crease group’ and 9 to the ‘periumbilical region group’.

**Reliability**

Clinician A detected a total of 133 perforators, clinician B a total of 122. Seventy-six of these were found on similar locations. A mean of 6.4 perforators were detected per square of which a mean of 3.8 were matching. More perforators were found in the umbilical region (a mean of 7.0 perforators) compared to the elbow region (a mean of 6.0 perforators). An overview of the amount of detected perforators per clinician in each group is given in Table 1. The mean DC was 0.56 (BCa 95% confidence interval of 0.47-0.65).

**Validity**

A mean positive predictive value rate was found to be 52.6% for clinician A and 57.4% for clinician B. Of the perforator locations that were found positive with Doppler but negative with Duplex, a mean of 32.4% were axial vessels and a mean of 45.1% were intramuscular situated vessels. The majority (70.6%) of these intramuscular situated perforators were found in the elbow region. See Table 2 for the detailed information.

**Discussion**

For the first time the reliability was assessed of the hand held Doppler as tool for the detection of perforators. The interobserver reliability of the Doppler device was remarkably poor, expressed by a Dice coefficient of 0.56. Also, 55% of the perforator locations found by Doppler were true perforators confirmed by Duplex, 45% of the locations detected with the Doppler were not confirmed by Duplex. These results implicate that the Doppler as a single device does not suffice in identifying perforator locations.

Surprisingly, so far no studies were performed on the reliability of the Doppler device, which is a basic requirement of a diagnostic device. Literature on the validity of the Doppler for detecting perforators has shown variable results. Giunta et al. and Ensat et al. found positive
predictive value rates of 52% and 69%, respectively\textsuperscript{11,13}. Two other studies reported higher positive predictive value rates varying from 82 to 94\%\textsuperscript{14,16}. Also, high sensitivity rates were presented in previous studies (varying from 81 to 100\%)\textsuperscript{11,12,16}. The higher positive predictive value and sensitivity rates in previous studies compared to the present study may be explained by the difference in study design; these studies investigated the validity of Doppler for the detection of established perforators, such as the DIEP\textsuperscript{10,11,13}, the superior gluteal artery perforator\textsuperscript{11,13} and thoracodorsal artery perforator\textsuperscript{11}. On the contrary, we focused on the Doppler as a diagnostic tool to detect all perforators within a square of 7x7 cm, so also smaller perforators. These perforators are located more dispersed and may differ in diameter, which most likely results in a lower positive predictive value. Taylor et al already demonstrated that the body contains a few hundred perforators with a diameter larger than 0.5 mm\textsuperscript{3}. The total number is expected to be much larger since also smaller perforators (<0.5 mm) can be detected with the hand held Doppler. This study was the first to assess the validity of the Hand held Doppler for the detection of these smaller perforators. This is particularly relevant now that not only larger perforators, but also smaller perforators are used for local ad hoc flaps.

In this study Duplex was chosen as standard of comparison because this technology has been shown to validly identify the position of perforators preoperatively in the setting of all types of flaps\textsuperscript{8}. Nonetheless, comparisons with more modern technologies such as CTA and MRA showed that color duplex was less accurate and provides less information on the intramuscular course of vessels. However, considering the purpose of our study -detection of smaller perforators- and the radiation hazards for the volunteers, we deemed Duplex as most appropriate standard of comparison for this study. Most studies compared the locations found using Duplex with locations found during operation\textsuperscript{11,13}. A disadvantage of this method of comparison is that when the skin is incised the location changes, which makes it difficult to evaluate if the location found intraoperatively actually corresponds to the location that was marked on the skin preoperatively.

A limitation of the present study, which also accounts for many of the previously mentioned studies\textsuperscript{11,13-16}, is that the validity was not tested independently. The intentional set up of this study was to assess the validity independently: perform a Duplex without knowing the locations found with Doppler. This strategy however, appeared unattainable in clinical practice because of the time it took for the laboratory technician to perform the Duplex. A consequence of dependently assessing the validity is that the measurements become subject to expectation bias, which occurs when the interpretation of the outcome is subconsciously influenced by the knowledge of previously measured outcomes\textsuperscript{17}. This may lead to higher positive predictive values.

We found that 45\% of the positive signals assessed by the Doppler were not confirmed by Duplex and therefore assessed as false positives. Of these false positives 32\% were axial vessels and 45\% were intramuscular vessels. Both types are inappropriate for the use for ad hoc perforator flaps. The amount of false positives caused by intramuscular vessels was larger in the elbow region than in the umbilical region, probably because the subcutaneous fat layer is usually thinner in the elbow region. A considerable amount of false positives were found in the umbilical region, which is striking since this region is frequently used for reconstructions. These findings illustrate that the Doppler does not provide enough information to sufficiently distinguish these different types of vessels from perforators.

The Doppler, however, remains a popular tool in the determination of perforator locations in clinical practice. Especially in the upcoming field of ad hoc perforator flaps, the Doppler device is commonly used for perforator detection\textsuperscript{1-6}. There are several practical advantages, like easy handling and the possibility for peroperative use, which enables direct monitoring during operation. Until now, the more advanced techniques are incapable of peroperative localization. This study does not aim to banish the Doppler as a diagnostic tool for the detection of perforators, as its beneficial properties might perform well when the device is used complementary to a more advanced technique such as Duplex. The complementary use of Doppler to Duplex may be carried out as follows: the perforator is located and assessed for suitability (e.g., not situated intramuscular or axial) with Duplex. Subsequently, Doppler is used peroperatively to confirm the location and to monitor the viability of the perforator during the operation procedure. In this way the Doppler is used as a monitoring tool instead of a single diagnostic tool thereby optimally utilizing the valuable properties of both techniques. An interesting line of research would be to carry out validity analysis for the Doppler used as a monitoring tool.

**Conclusions**

In conclusion, this study reveals novel and essential clinimetric properties of the hand held Doppler device. We have shown that Doppler is not suitable as a single diagnostic tool for the detection of perforators. This is an important finding in the field of reconstructive surgery where Doppler is frequently used for the detection of perforators for the use of ad hoc perforator flaps.

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