*Original Article*

# A Comparison of Accuracy between Dynamic Infrared Thermography (DIRT) and Handheld Doppler Ultrasonography in Free Flap Reconstruction Perforator Mapping: A Prospective Study

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***Background:*** Preoperative perforator mapping is one of fundamental steps for successful surgery in microsurgical perforator free flap. Currently, there is still no gold standard for preoperative perforator mapping.

***Objective:*** The present study aims to compare accuracy in perforator mapping between dynamic infrared thermography (DIRT) and handheld doppler which is the main method we used in our hospital.

***Materials and Methods:*** Twenty patients scheduled for microsurgical free flap reconstruction between October 2018 to December 2020 was enrolled. Preoperative perforator mapping was performed by both handheld doppler and smartphone dynamic infrared thermography (DIRT). During rewarming period, "Hot spots" were marked. Then flaps were raised intraoperatively, numbers, diameter and location of each perforators were recorded. Location of perforators at its piercing fascia were reflected to skin. Distance from actual perforators to the nearest preoperative perforator marking point by each method were measured.

***Results:*** There were 9 male and 11 female patients enrolled in the present study with mean age of 54.30 years. The average body mass index was 23.85 kg/m$^2$. Hand-held doppler and DIRT images were obtained for 20 flaps, including 15 anterolateral thigh flaps (75%), 1 anteromedial thigh flap (5%) and 4 fibular free flaps (20%). The mean caliber of selected perforators was 2.62 mm at point of their emergence through fascia. All the flap survived without postoperative major complication. The mean distance from actual perforator to the nearest perforator from handheld doppler was 11.88$\pm$7.51 mm, and to the nearest perforator from thermal images was 12.68$\pm$8.96 mm. The mean distance difference of both methods was 0.80 mm. Perforators were usually within a 20 mm radius of preoperative marking both handheld doppler and DIRT.

***Conclusion:*** Dynamic infrared thermography is low cost, non-invasive and reliable methods for preoperative perforator mapping.

***Keywords:*** Dynamic infrared thermography; Handheld doppler ultrasonography; Perforator mapping; DIRT; Perforator free flap

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Perforator flaps are widely used for reconstruction. Surgeon can design flap that match with exact size and component of defect with less donor site morbidity. The selected perforator is crucial for flap survival as it is the only source of blood supply to the flap. Many imaging modality are currently used to assess patients preoperatively in microvascular reconstructive surgery such as hand-held Doppler, Color Doppler ultrasonography (CDU), Computer Tomography Angiography (CTA) and Magnetic Resonance Angiography (MRA).

Multicenter consensus study considered CTA the preferred method for preoperative perforator mapping as its can identify perforator location and intramuscular course. The main disadvantages of CTA are exposure to intravenous contrast and radiation, high cost and not available in all hospital.

Handheld Doppler is the widely used technique for perforator mapping. It is simple, easy to use and available in almost all hospital. Handheld Doppler identified perforator from arterial Doppler sounds. We can inferred that the loudest point is the dominant perforator. Klasson et al published that there is no difference in surgery time and complication rate when handheld doppler is used for preoperative perforator mapping in comparison with CTA. This technique has high sensitivity and high false positive rate. The detected perforators sometimes are small and not suitable ones.

Dynamic infrared thermography (DIRT) is widely used for postoperative flap monitoring and currently increase using for preoperative perforator mapping. It provides

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dynamic, real-time, intraoperative information about vessel location, perfusion patterns and flap physiology. Many studies purposed that DIRT is valuable method for preoperative perforator mapping. The first appearing hot spots on DIRT were always associated with arterial Doppler sounds and intraoperative findings.

In our hospital, handheld Doppler is the main technique we use to do pre-operative perforator mapping which can correctly identify perforators but It also has drawbacks because of its high sensitivity. We could not identify the dominant perforator by pre-operative mapping and we often found that near arterial Doppler sounds reflected the course of one perforator. Weum et al reported that the speed and progression of rewarming at the "hot spot" provides information regarding the caliber of the perforator and its surrounding vascular network which we believe can help identify the dominant perforators. It might be beneficial for the patients if DIRT could replace handheld Doppler. This study aims to compare the accuracy of handheld Doppler and DIRT in preoperative perforator mapping.

## Materials and Methods

This prospective clinical study was approved by the Committee for Research Ethics (No. MURA2019/897). After giving informed consent to participation and publication of data. Patient who scheduled for microsurgical free flap reconstruction during December 2017 to November 2020 were included. The flap was marked by anatomical landmarks of each flap then perforator mapping was performed with hand-held Doppler and DIRT.

Hand-held Doppler (8 MHz, Multi Dopplex, Huntleigh Healthcare, Cardiff, UK) was used to locate arterial doppler sounds and were marked as red dots on skin.

An infrared camera FLIR ONE (FLIR Systems, Wilsonville, Oregon) was used to capture thermal images before and after exposure of flap to a cold challenge. The cold challenge was performed by using cold pack over skin flap for 5 minutes then the infrared thermography camera was used to continuously monitor the area throughout rewarming phase. The first areas that rewarm are the perforators and appear as hot spots. The first appearing hot spot was registered and named with increasing identification numbers based on their order of appearance. Each identified hot spot was marked as perforator using blue skin marker (Figure 1A,B).

### *Intraoperative phase*

After completing the preoperative mapping. Patient was brought to the operating room. Flap was raised in subfascial plane, all perforators were identified. The sizeable perforators were located and their emergence through fascia were marked at identical location on skin (Figure 2A,B). The distance from actual location of perforators where their existed through deep fascia to the nearest pre-operative Hand-held dopplers and DIRT skin marking points were measured (Figure 3).

The parameters that followed a normal distribution

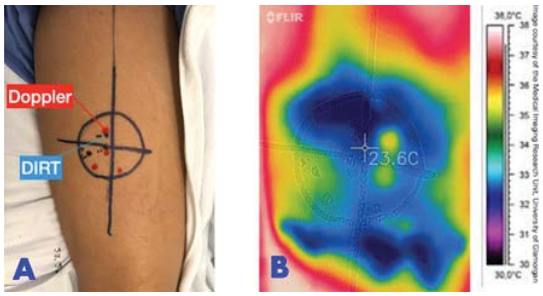


**Figure 1.** A) Pre-operative perforator mapping of ALT flap by DIRT (blue dot) and handheld Doppler (red dot), B) Thermography shows "Hot spot" that represent perforator piercing point.

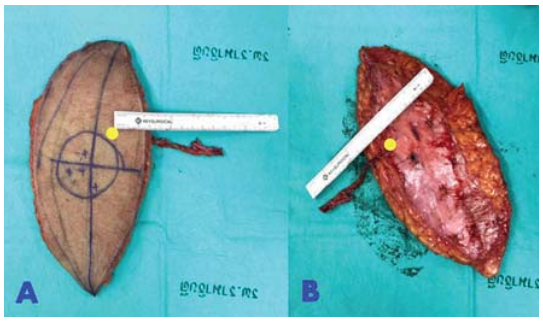


**Figure 2.** A, B) Perforator was identified by direct vision intraoperatively.

were compared using t-test; otherwise Wilcoxon signed-rank test was adopted. The Agreement test between handheld doppler and DIRT was obtained from Intraclass Correlation Coefficient (ICC) generated by Two-Way Mixed-Effects model with 95% confidence intervals (CIs) and a p-value less than 0.05 was considered as statistically significant. All statistical analysis was performed with STATA software (version 14).

## Results

There were 9 male and 11 female patients enrolled in this study with mean age of 54.30 years. The average body mass index was 23.85 kg/m$^2$. Hand-held doppler and DIRT images were obtained for 20 patients, including 15 anterolateral thigh flaps (75%), 1 anteromedial thigh flaps (5%) and 4 fibular free flap (20%) (Table 1). 110 dominant perforators were identified by hand-held doppler and 75 hot spots were identified on thermal images obtained with FLIR camera. Intraoperatively, the mean caliber of selected perforators was 2.62 mm at point of their emergence through fascia. All the flap survived without postoperative major complication.

The location of perforators identified by hand-

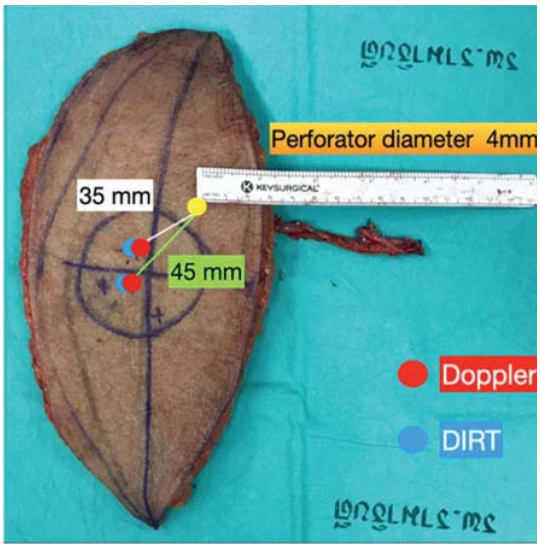


**Figure 3.** The distance from actual location of perforator to the nearest preoperative skin marking by both methods were measured.

**Table 1.** Patient characteristics

| | Mean±SD | Median (IQR) |
|---|---|---|
| Perforator diameter (mm) | 2.62±0.88 | 3 (2, 3) |
| Distance from perforator (mm) | | |
| Doppler | 11.88±7.51 | 10 (8, 13) |
| FLIR No. 1 | 12.68±8.96 | 10 (10, 14) |
| Difference (mm) | -0.80±6.90 | 0 (-4, 0) |

held doppler and DIRT were compared with intraoperative findings. The mean distance from actual perforator to the nearest perforator from hand-held doppler was 11.88 mm, and to the nearest perforator from thermal images was 12.68 mm. The mean of distance differences from the same point was 0.80 mm (Table 2) and both measurements were always within a 20 mm radius.

## Discussion

Preoperative perforator mapping optimizes flap design, reduce operative time and become the important factor for operative success. Based on current evidence CTA is advocated as the modality of choice for preoperative perforator mapping. CTA can demonstrate the location, size and also course of perforators. However, its requires administration of intravenous contrast, exposure to radiation, cannot be used in patients with renal impairment. It has high cost and not available in all hospital.

The handheld Doppler has several advantages as it easy to perform, portable and widely available in most hospitals. Many studies published promising results for preoperative perforator mapping in comparison with CTA. However, it was observed that the reliability of the Doppler sound depends on the size of vessels. The background noises often decrease its specificity and its sensitivity is too high to detect adequate arteries and course of its. Giunta et al evaluated using the handheld Doppler in 46 patients undergoing breast reconstruction demonstrated high false-positive rate of 46.7% and false-negative rate 11.0% which compatible with data previously mention. They also found that location of each perforator approximately 1 square centimetre from skin marking.

DIRT is widely use for postoperative flap monitoring and currently increase using for preoperative perforator mapping. Previous studies have shown that DIRT was a valuable technique in assisting the planning, harvesting and monitoring free flaps. Hardwicke first introduced the detection of perforators in the anterior abdominal wall and lateral thigh using a smartphone-compatible thermal imaging camera but their value in detection of PAPs remains unclear. Chen R studied in fibular flap reconstruction, concluded that the sensitivity and positive predictive value of the smartphone-compatible thermal imaging camera are low. It should be used as an adjective tool together with established imaging techniques. However, Weum et al reported that hot spots on DIRT images were always associated with arterial Doppler sound and clearly visible on CTA which confirms that DIRT is a promising alternative to CTA for preoperative perforator mapping.

The main goal of preoperative perforator mapping is to locate suitable perforators which ia an important factor for flap survival. Correctly identify dominant perforator is more important than precise mapping of all perforators. But intraoperative findings will help select the proper and larger perforator.

Our study demonstrated high concordance in perforator mapping between handheld Doppler and DIRT 70% of cases. Although handheld Doppler had more accuracy in perforator identification compared to DIRT but had no statistically significant difference (p=0.493). Both methods successfully identified perforators in all cases.

When comparing distance from suitable perforators >1 mm to the nearest hot spot and arterial Doppler sound. The perforators was usually within 20 mm - radius from preoperative marking points by both handheld Doppler and DIRT (Figure 4) which similar with results from Pereira et al. An explanation is that fascial emergence perforators travelling subcutaneous fat to skin in both vertical and oblique axis.

Subcutaneous thickness is a major factor that affects accuracy of both techniques and imaging quality of thermal images. In anterolateral thigh flap the concordance in perforator mapping both both techniques is more than in fibular flap. We found rapid rewarming phase in fibular flap which made its difficult for hot spots identification (Figure 5). Arai first described the use of DIRT for perforator mapping in DIEP flaps in 1993[8]. Perforators that transport

**Table 2.** Mean distance from actual location of perforator to the nearest pre-operative skin marking by both methods

| Data | Total (n=20) |
|---|---|
| Gender, n (%) | |
| Male | 9 (45.00) |
| Female | 11 (55.00) |
| Age (year), mean±SD | 54.30±17.44 |
| BMI, mean±SD | 23.85±3.62 |
| Underlying disease, n (%) | |
| DM | 2 (10.00) |
| HT | 6 (30.00) |
| DLP | 4 (20.00) |
| Smoking, n (%) | |
| No | 13 (65.00) |
| Yes | 7 (35.00) |
| Pack–year, median (IQR) | 26 (15, 30) |
| Smoking cessation prior to surgery (month), median (IQR) | 3 (2, 4) |
| Flap, n (%) | |
| Anterolateral thigh | 15 (75.00) |
| Anteromedial thigh | 1 (5.00) |
| Fibula | 4 (20.00) |

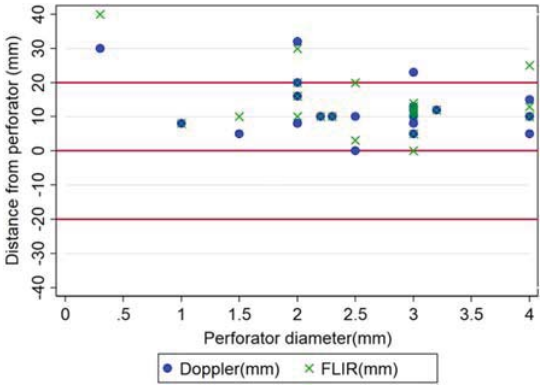


**Figure 4.** Accuracy between handheld doppler and dynamic infrared thermography (DIRT).

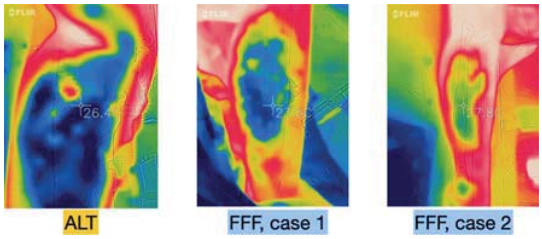


**Figure 5.** Rapid rewarming phase in fibular flap made its difficult to identify hot spot.

blood to the subdermal plexus cause a local heating at the skin surface that can be visualized as hot spots on infrared images. Fibular flap has thinner fat compare to anterolateral thigh flap. The core body heat is easily transmitted to skin make the temperature between skin and perforator piecing point less difference which interferes hot spots observation.

Some disadvantages of DIRT is that only perforators that transport blood to the skin surface are detected. It is possible that a perforator that ends in the subcutaneous tissue might be a suitable perforator.

The main limitation of this study is small number of patients. For prevalence adjusted statistics and population level conclusions a larger study is required. We only measured the distance from suitable perforators to the nearest marking points by both techniques which may missed information of other perforators resulted in underestimated data.

## Conclusion

Preoperative perforator mapping is the important step that effect flap survival. In our study handheld Doppler have a high concordance with smartphone compatible thermal images in perforator mapping. Suitable perforators were successfully identified by both techniques. DIRT provides promising location of perforators. Further studies are required to evaluate rewarming pattern which could refer to hemodynamic properties of each perforators.

## What is already known on this topic?

No gold standard for preoperative perforator mapping. Handheld Doppler is the widely used technique for perforator mapping. It is simple, easy to use and available in almost all hospital. Nowadays DIRT is also widely use for postoperative flap monitoring and currently increase using for preoperative perforator mapping but no study about accuracy of DIRT compared with Handheld Doppler.

## What this study adds?

DIRT is one of accuracy tool for preoperative perforator mapping.


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## Potential conflicts of interest

The authors declare no conflict of interest.

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