



Dynamic infrared mapping of cutaneous perforators

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Abstract: Perforator flaps have become the “gold standard” for most reconstructive procedures, replacing the conventional axial and musculocutaneous flaps. However, these flaps are a lot harder to harvest, much of the difficulty being attributable to correctly identifying and dissecting the ideal perforator in each case. Therefore, preoperative perforator mapping has become an integral part of the reconstructive protocol in many institutions. Many different imaging techniques are currently used for perforator mapping, however, they all have drawbacks, whether its exposure to radiation, high costs or operator dependence. Dynamic infrared thermography (DIRT) is a fairly new imaging technique, showing promising results, in preoperative perforator mapping, intraoperative perfusion assessment and postoperative flap monitoring. The technique is safe, fast, noninvasive, cost effective and reliable.

Keywords: Perforator flaps; perforator mapping; dynamic infrared thermography (DIRT)

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Introduction

Flap design has evolved constantly over the last decades, culminating with the introduction of flaps harvested on a single perforator back in 1989 (1). Since then, their use has grown exponentially, perforator flaps having replaced axial and musculocutaneous flaps in the vast majority of reconstructive procedures. However, these flaps are a lot harder to harvest, much of the difficulty being attributable to correctly identifying and dissecting the ideal perforator in each case. Therefore, preoperative perforator mapping has become an integral part of the reconstructive protocol in many institutions (2).

Out of the numerous imaging modalities used for perforator mapping, handheld Doppler ultra-sound, color Doppler imaging, computed tomography (CT) angiography, and MRI are worth mentioning. Currently, CT Angiography is considered the “gold standard”, providing reliable results, fast and with minimal patient discomfort (3). However, all these techniques have drawbacks, whether its exposure to radiation, high costs or operator dependence.

Dynamic infrared thermography (DIRT) is a fairly

new imaging technique, showing promising results, in preoperative perforator mapping, intraoperative perfusion assessment and postoperative flap monitoring (4). The technique is based on visualizing the infrared radiation (IR) emitted by the skin, and correlating it with tissue temperature. The mapping technique was first described by Itoh and Arai (5), and then de Weerd (6) in 2006, followed by a series of studies by Chubb and Taylor (7) that emphasize the value of thermography not only for perforator mapping but also for identifying the connections between perforasomes. DIRT is a safe, fast, noninvasive, cost effective and reliable method of perforator mapping.

Basic science

The human body emits heat in the form of IR. The IR wavelength is a part of the non-visible electromagnetic spectrum (700 nm – 1 mm) and is perceived as heat. The amount of IR radiation emitted is determined by the temperature of the skin (8). Because cutaneous temperature depends on vascularization (9), IR skin emission mirrors its blood supply. Older thermal cameras were cumbersome and



Figure 1 The Testo 890 (Testo AG, Lenzkirch, Germany) is an inexpensive example of a thermal camera for imaging.

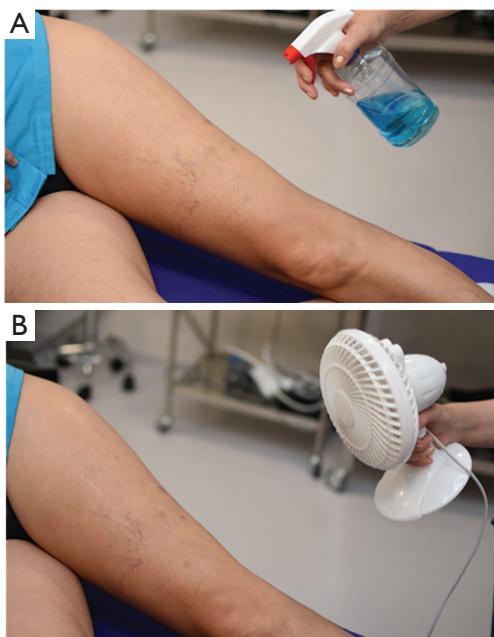


Figure 2 Application of cold challenge for temporary skin ischemia. (A) To visualize the location of perforators, a thermographic stress or “cold challenge” is induced by first spraying a rapidly evaporating alcoholic solution on the chosen donor site skin; (B) the cooler air from a fan hastens evaporation to cool the area below normal body temperature.

had a low thermal sensitivity, without the capacity to perceive subtle differences in temperature. The new generation of thermal cameras, however, have a thermal sensitivity of <40 mk and can pick-up differences of 0.04 °C (10). This, plus

advances in image post-processing software, has reignited the interest for medical thermography. The IR recorded images are processed by the camera and displayed as a color-coded map. A “rainbow” color scheme is normally used, higher temperatures appearing as red, while lower temperatures are depicted in blue. This allows for a very simple interpretation of the data, making the technique straightforward and operator friendly.

Equipment and technique

The perforator mapping can be done the day before or in the operating room just before the procedure. The equipment required for DIRT is simple and relatively non-expensive, when compared with other imaging modalities. All that is required is a thermal camera (*Figure 1*) [Testo 890 (Testo AG, Lenzkirch, Germany)] and any machine capable of blowing cold air, for example a fan (*Figure 2*). The idea behind dynamic thermography mapping of perforators relies on recording the thermal recovery of the skin after an induced cold challenge.

After the flap is outlined, an alcohol based solution is sprayed and cold air is blown on the skin surface for a couple of minutes ($\cong 3$ min), until the area is evenly cooled to a temperature well below that of the normal skin, roughly 20 °C. The temperature is monitored with the thermal camera. Once the temperature is low enough, the cooling stops and the flap is allowed to rewarm (11).

Because of skin vascularization through perforators, as the temperature recovers, they are visualized first. The rewarming phase is monitored in real time through the thermography camera, recording the initial bright spots that appear, or “hot spots”, and marking them as perforators (*Figure 3*). The sequence of hot spots visualization and signal intensity mirrors the skin vascular supply. The bigger, “dominant” perforators, always appear first and generate a stronger signal (12). This also indicates a well-developed vascular network around the perforator. After all the perforators are marked, the thermography is repeated, confirming the location of the dominant perforator (*Figure 4*). The sequence of expected visible color changes is shown in *Figures 5–9*. A final overlay of the thermographic image on the normal skin where perforators have been marked will confirm their location (*Figure 10*).

Thermography identifies the perforators superficially, as they enter the skin. If the perforator is compared to a tree, thermography only visualizes the “crown”. For this

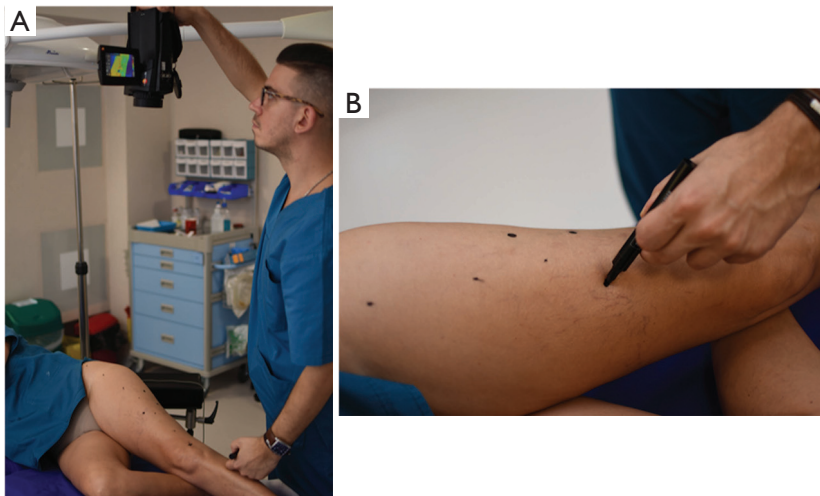


Figure 3 Thermography used to visualize perforators during rewarming phase. (A) After the cooling is complete, the skin is allowed to gradually rewarm. During this rewarming phase, the perforators are visualized with the thermography camera as bright spots, (B) and these “hot-spots” are marked on the donor site.

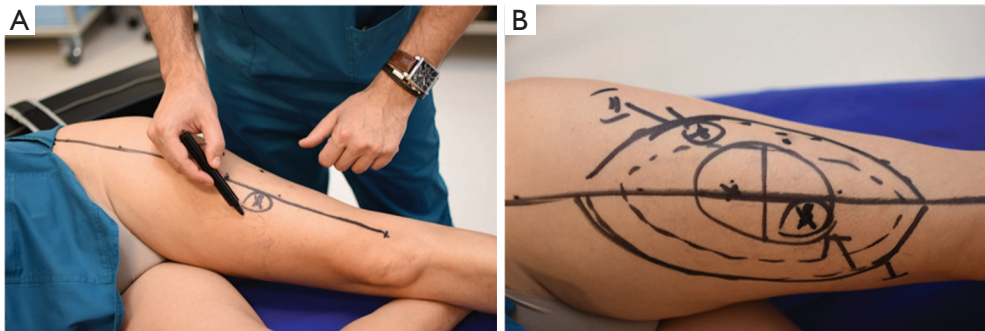


Figure 4 Entire process of cooling and rewarming repeated to confirm perforator location. (A) After the initial thermographic marking of all perforators is performed, the process is repeated to confirm the location of the dominant perforator, that here is separately encircled on the skin, (B) about which the desired flap design is drawn.

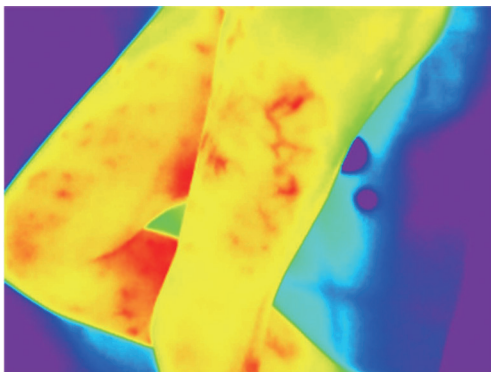


Figure 5 Initial DIRT image of the thigh showing appearance of normal body temperature. DIRT, dynamic infrared thermography.

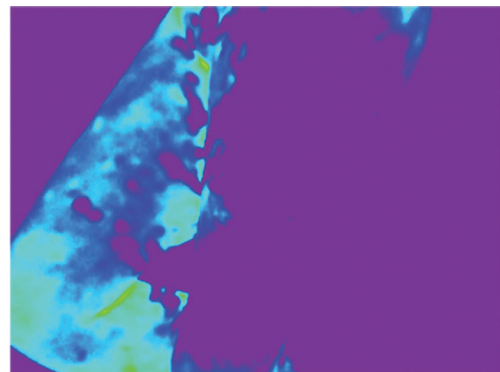


Figure 6 After induction of the “cold challenge,” uniform cooling of the skin is seen as a dark blue color.

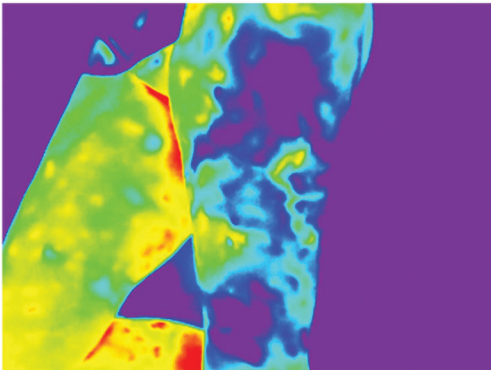


Figure 7 During the initial rewarming phase, the perforators are first visible as bright spots on a blue background or “hot spots”, and these are marked on the skin.

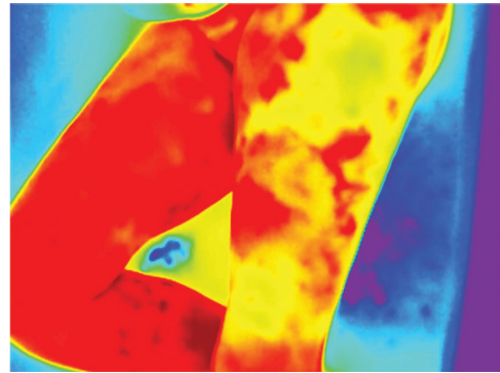


Figure 9 Final thermography appearance in this sequence showing completion of rewarming.

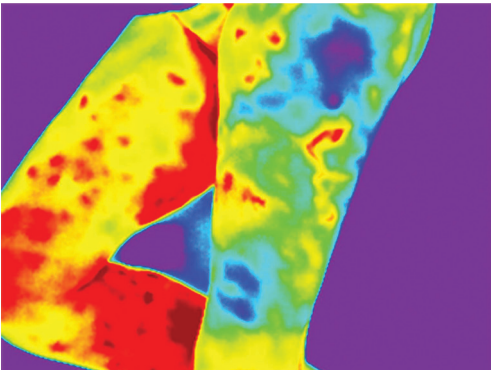


Figure 8 The process is repeated to confirm and mark the location of the dominant perforator, where rewarming will occur most rapidly and seen as a transition to the red side of the visual spectrum.

reason, it is possible to record multiple “hot spots” for one perforator, because perforators occasionally branch. For this same reason, as some perforators have a slightly oblique course from the fascia to the skin, their registered “hot spot” may deviate from the actual fascial emergence. However, according to studies carried out by Giunta *et al.* the average of this deviation is about 8 mm (13).

Conclusions

DIRT mapping of cutaneous perforators is a fast, reliable, safe and non-expensive method of perforator mapping. It does not employ contrast material or radiation. The examination technique is simple, easy to learn and operator friendly. However, it is a subjective test that requires

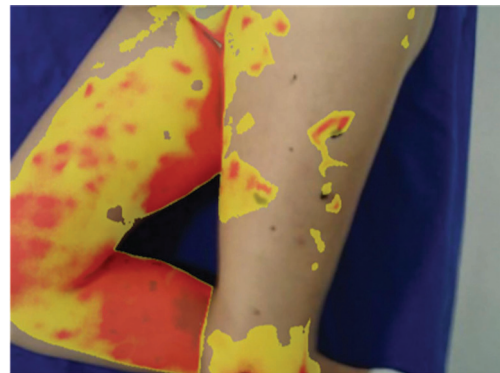


Figure 10 Note that if the thermography appearance were overlaid on the patient’s thigh, the “hot spots” would clearly coincide with the sites marked as perforators.

operator experience for accuracy. It can be used as a stand-alone mapping tool or in adjunct with other techniques such as audible Doppler ultrasound (14). DIRT delivers accurate and reproducible results when compared CTA (15) and the audible Doppler, without the drawbacks associated with these techniques. Further research into this emerging field will establish the place of DIRT in the modern plastic surgery armamentarium.

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