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ORIGINAL ARTICLE

Thermal Camera for Detection of Perforator Territories in Fasciocutaneous Flaps for Leg Reconstruction

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Abstract

Background: **Soft tissue abnormalities are often repaired utilizing perforator flaps. Accurate understanding of underlying vascular architecture and the precise positioning of perforators is essential for successful surgery. Dissection can be difficult because the path and placement of perforators might vary widely.**

Aim: **This study aims to evaluate skin flaps taken from the legs to see how well thermal imaging cameras can diagnose perforators and their respective territories on the skin.**

Methodology: **This interventional prospective case series study was conducted in the plastic and reconstructive surgery unit, Azhar University Hospitals between July 2021 and April 2023 on 12 male patients and eight female patients with leg soft tissue defects undergoing leg reconstruction surgeries.**

Results: **In 20 patients undergoing perforator flap surgery, adequate 'hot spots' were not found in one patient. The remaining 19 individuals all received flaps. All proper assessments were made utilizing intra-operative thermograms, which indicated 100% flap survival for 17 flaps and marginal ischemia for 2 flaps. Only the flaps that were repaired by secondary purpose had dehiscence, whereas the remainder healed normally.**

Conclusion: **The Thermal Camera is a fast, simple, low-cost, and reliable way to detect perforators in the lower leg, making it a valuable tool for mapping perforators in free-style perforator flaps design.**

Keywords: Fasciocutaneous flaps, Leg reconstruction, Perforator territories, Thermal camera

1. Introduction

Perforator flaps are frequently utilized to repair soft tissue abnormalities. For a surgeon to be successful, they must have a thorough understanding of the underlying vascular architecture and the precise position of perforators. When perforators take different paths or are located in different places, dissection might be difficult.[1]

There have been several cadaver and human studies that have served as landmarks in the search for the artery that supplies blood to the skin. Several approaches in finding perforators for flaps, handheld Doppler, Duplex ultrasonography, computed tomography, and magnetic resonance angiography and thermography technologies have been utilized preoperatively to detect the position of the perforating vessels.[2]

Each strategy is fraught with serious drawbacks. The handheld Doppler ultrasound might provide erroneous positive or negative readings. Duplex ultrasonography, computed tomography, and magnetic resonance angiography all involve subjective results that are valued based on the radiologist's level of experience and training. They are also more difficult to get and more costly since they put patients at risk from intravenous contrast.[3]

The effectiveness of reconstructive surgery needs to have a noncontact, noninvasive method for the

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identification and preservation of perforators that the plastic surgeon may utilize frequently.[4]

The purpose of this research was to evaluate the diagnostic efficacy of a thermal imaging camera for identifying lower limp flap areas and perforators.

2. Patients and methods

Between July 2021 and April 2023, leg soft tissue defects were recontstructed by pedicled free style perforator flap in 20 patients, all of whom gave informed written consent for participation. World Medical Association Declaration of Helsinki and Al-Azhar Plastic Surgery Department Scientific Council guidelines were followed throughout this research. Twelve participants were male and eight were female and their ages varied from 15 to 40 years (mean 25 years).

Each individual were selected from those people looked for treatment in the outpatient clinic and emergency room (ER) at both plastic surgery department, Al-Hussien and Bab Elsheria Hospital, Faculty of Medicine, Al-Azhar university (Cairo).

The research enrolled 20 cases with mean age of 32.45 ± 6.73 years and ranged from 32 to 76 weeks, 65% of patients were males with a mean BMI was 25.31 kg/m^2, that 14 (70%) patients had flap due to trauma, four (20%) patients were due to post tumor excision and two (10%) patients were due to osteomyelitis and unstable scar, 10 patients had flaps based on posterior tibial artery perforators, 4 based on anterior tibial artery perforators, 3 based on peroneal artery perforators and 3 on medial sural artery. 13 (65%) patients had flap on the right side, and 35% of patients had flap on the left side. The mean flap size 62.44 ± 19.72 cm^2 with mean hospital stay 7.83 ± 2.14 days and mean healing time 28.50 ± 3.67 days.

Inclusion criteria: all patient's included in the study have fulfilled the following criteria: Age: 10–60 years old, Sex: male and female, and Cause: any cause of leg soft tissue defects.

Exclusion criteria: patients with hyperthermia (>37.5 °C) or hypothermia (<37 °C) were excluded as this could affect perforator detection and thermogram and patients with peripheral vascular diseases, diabetes mellitus, and cardiac or renal problems.

Ethical considerations: time was be spent with patients and their families, explaining the procedures and thermal camera technique in detail utilizing photographs, video imaging as well as discussions with other patients who have undergone the procedure. An explanation of the research project will be given to the patient and/or their parents. Individuals and/or their parents who participate in the research will be asked to sign a permission form.

For each participant the following records were taken: preoperative and postoperative photographs (anterior, lateral, medial and posterior views).

Surgical technique: Preoperative: the donor site was sprayed with isopropyl alcohol, a portable fan was utilized, or ice was applied to speed up the chilling process. Estonian-made thermal imaging camera (compatible with smartphones) Flir One Pro with cost ranges from 300 to 400 dollars was utilized to locate the perforator. This compact infrared camera employs a sensor with a working temperature range of 0 to 100 °C and a wavelength of between 8 and 14 μm, however, the resulting image has a lesser resolution and a smaller temperature detection range than that of more costly thermal imaging cameras. By detecting infrared radiations, thermal imaging systems that generate thermograms can infer cutaneous blood flow as a surrogate measure. After thermal recovery (about 3 min) sequential thermograms were taken which show cutaneous hot spots, these hot spots denotes location of perforators which supply the overlying skin. These steps takes around 5 min to located perforator sites and its suppling territory and needs no prerequesties.

Intraoperative: after exploration, if multiple perforators are found, each in turn can be clamped temporarily with a microvascular clamp and flap perfusion from each perforator assessed by evaluating the resulting thermogram.

Postoperative: maintenance of bright colors on thermogram proving a warm flap with good vascularity and adequate perfusion. A change in the thermogram if the observed color is darker implies diminished flow.

2.1. Case presentation

Case 1: male cases 30 years old suffers from a chronic ulcer at the posterior aspect of lt ankle joint, after depridment Achilles tendon was found exposed and planned to be reconstructed by posterior tibial artery perforator flap. The flap intraoperatively shows weak flow at its distal end and excised intraoperatively.

Case 2: Male patient 37 years old suffers from post traumatic chronic leg ulcer at anteromedial aspect of lower leg, reconstruction with advancement flap was planned (see Figs. 1 and 2).

3. Results

20 pedicled perforator flaps were performed to cover leg defects in 20 patients. We identified 62

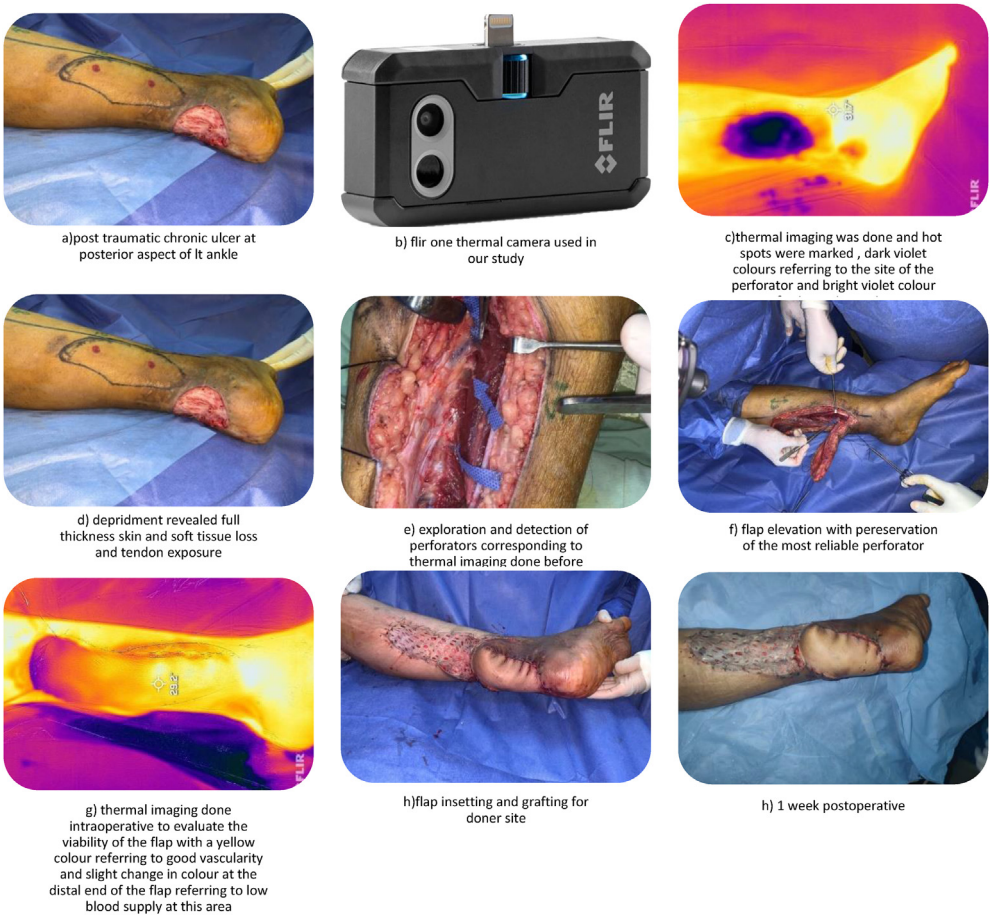

Fig. 1. Showing a post traumatic chronic ulcer located at posterior lower leg over achillis tendon, reconstruction was done by posterior tibial artery perforator flap.

perforators intraoperative and 66 hot spots by thermography. Inadequate 'hot spots' were not found in one patient. The other 19 patients had 19 flaps based on perforators detected by thermogram. There were no false positives or negatives in the intraoperative thermagrams that indicated 100% flap survival for 17 flaps and marginal ischemia for 2 flaps. Flaps that repaired by secondary intention were more likely to have dehiscence, although the majority healed without complication Table 1.

The study enrolled 20 patients with mean age of 13.45 ± 8.32 years and ranged from 8 to 43 weeks, there were (65%) of patients were males and (35%) Table 2.

We found that 14 (70%) patients had flap due to trauma, four (20%) patients were due to post tumor excision and two (10%) patients were due to osteomyelitis and unstable scar Table 3.

10 patients had flaps based on posterior tibial artery perforators, 4 based on anterior tibial artery perforators, 3 based on peroneal artery perforators and 3 on medial sural artery.

4. Discussion

Soft tissue abnormalities are often repaired utilizing perforator flaps. Accurate understanding of underlying vascular architecture and the precise positioning of perforators is essential for successful surgery. Dissection can be difficult because the path and placement of perforators might vary widely.

To validate thermal imaging in the identification of perforators and territories, the results of thermal imaging were proved intraoperatively as we found the perforators corresponding to the thermal imaging maping done preoperatively.

Our results indicated that thermal imaging was significant in the identification of perforators and territories with sensitivity of 88.9%, specificity of 100%, negative predictive value (NPV) of 50% and positive predictive value (PPV) of 100% with accuracy of 90%.

The application of thermal imaging for vascular mapping eliminates the need for contrast agents or radiation and is performed without touching the

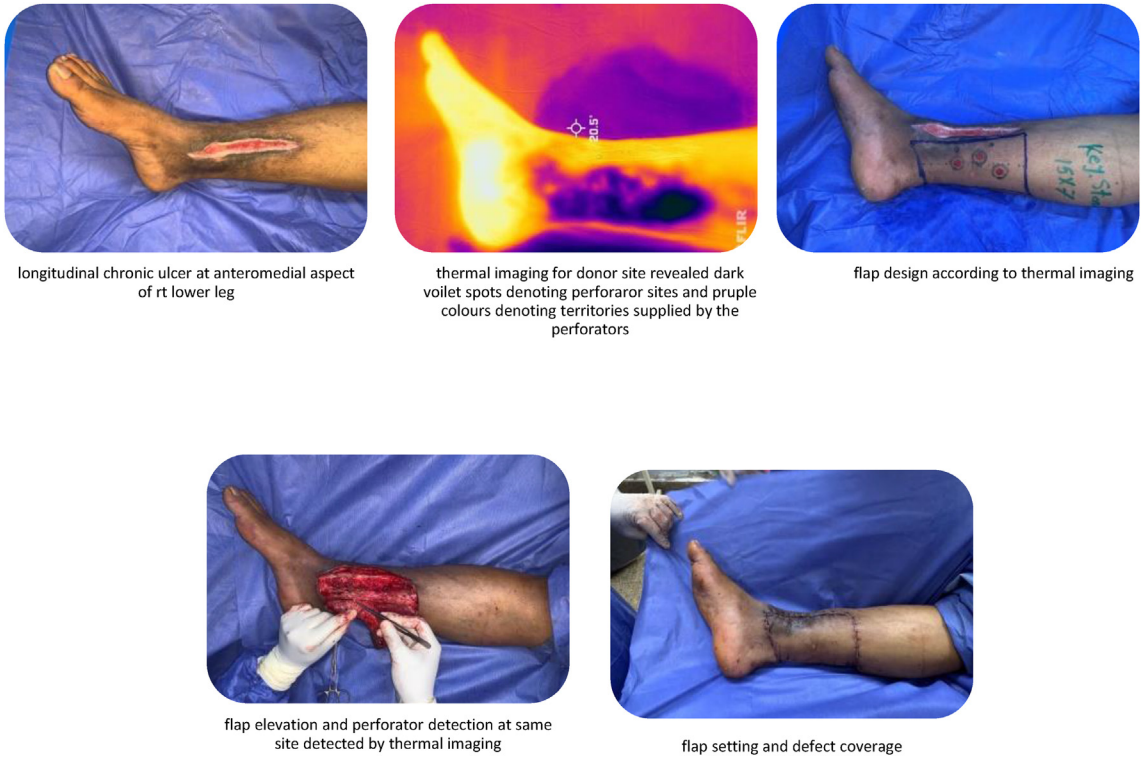

Fig. 2. Longitudinal chronic ulcer at anteromedial aspect of rt lower leg, reconstruction was done by a key-stone flap.

Table 1. Demographic data between the studied population.

	No. = 20	
Age	Mean ± SD	13.45 ± 8.32
	Range	8–43
Sex	Male	13 (65.0%)
	Female	7 (35.0%)

Table 2. Causes of flap between the studied population.

Cause	No. (%)
Trauma	14 (70.0%)
Post osteomyelitis	1 (5.0%)
Post traumatic unstable scar	1 (5.0%)
Post tumor resection	4 (20.0%)

patient. Even while perforator hotspots are easily recognized with hand-held doppler ultrasonography, localization and confirmation are hindered by background thermal interference and artifact, the skin only needs a few time of acclimation to ambient temperature. With the widespread availability of real-time thermal imaging today, it should be utilized in concert with other technologies to give additional clinical information useful in the evaluation, performance, and follow-up monitoring of tissue transfers. This little equipment is ideal for rapid screening and mapping, and it is very portable. The Flir One's resolution is not quite as high as that of higher-end thermal imaging cameras, but it is still a very inexpensive option that may be used in a variety of reconstructive and aesthetic procedures.

Table 3. Arteries flap based upon between the studied population.

Arteries flap based upon	No. (%)
Anterior tibial artery	4 (20.0%)
Posterior tibial artery	10 (50.0%)
Peroneal tibial artery	3 (15.0%)
Sural artery	3 (15.0%)

Pereira *et al.*, using the anterolateral thigh flap region as a reference, assessed the concordance between thermographic pictures acquired with a smartphone thermal camera and computed tomographic angiography for identifying perforators, lending credence to our findings. Twenty patients participated, with a total of 38 anterolateral thigh flap areas, and 117 perforators were found utilizing computed tomographic angiography, while 120 hotspots were found using thermography. Both measures were acquired within a 20 mm radius, with a concordance kappa value of 0.975 ($P < 0.001$), yielding an average mean distance of 193.14 mm from the anterior superior iliac spine. Employing thermographic imaging, we found a sensitivity of 100% and a specificity of 98% for locating perforators. Thermal pictures captured with a smartphone

demonstrate a high degree of agreement with the approach regarded as the gold standard for perforator detection. The approach is highly effective for mapping perforators in free flap planning, and its sensitivity and specificity are on par with those of computed tomographic angiography.[5]

Furthermore, utilizing intraoperative eye examination as the gold standard, Rabbani and colleagues assessed the diagnostic accuracy of a thermal imaging camera for identifying perforators. The selected patient population had a mean age of 23.34 + 6.06 years (range: 16–38 years old). There were 125 (67.93%) men and 59 (32.07%) females. There were a total of 69 (37.50%) flaps taken from the abdomen, 69 (37.50%) from the groin, and 44 (23.91%) from the upper limbs. Eighty-three percent of the flaps were attached by pedicles, whereas sixteen percent were attached by free flaps. According to the results, the positive predictive value of a thermal imaging scan is 98.7%, the negative predictive value is 25%, the sensitivity is 86.2%, the specificity is 80%, and the diagnostic accuracy is 85.9%.[6]

Supporting our findings was the work of Afzal and colleagues who detailed the use of smartphone-based dynamic thermal imaging in the planning and execution of pedicled perforator flaps and compared it with doppler. The time it took to identify the primary perforators was also compared. 15 participants enrolled in the trial, 11 (73.3%) were male and four (26.7%) were female. The ages ranged from 13 to 62, with the mean age being 35.9 ± 16.3. Twenty-two of the 23 thermally identified dominating perforators were confirmed intraoperatively (positive predictive value = 95.7%), but only 23 of the 32 perforators identified by doppler were (positive predictive value = 68.8%). Doppler has a longer average duration of 598.47 ± 192.94 s compared with thermal imaging's 591.27 ± 252.48. There were two instances of delayed flap. One example of partial flap necrosis was seen. Pedicled perforator flaps for lower limb reconstruction can be safely planned with the use of dynamic thermal imaging.[7]

Perforator identification in distal lower leg reconstruction was another goal of Pan *et al.*, who also sought to evaluate the use of thermographic imaging supplemented with tourniquet-reperfusion. Positive predictive value was 93.3% and sensitivity was 90.3% for the tourniquet-reperfusion augmented thermal imaging technique (TRATIM). There was remarkable agreement between TRATIM and computed tomography angiography (CTA), with a kappa score of 0.839 ($P < 0.001$). For the distal lower leg resurfacing, 9 propeller perforator flaps were developed and successfully implanted based on the TRATIM. The only flap that didn't make it was a 1 × 2 cm one that developed terminal necrosis.[8]

Hallock, investigated smartphone thermography to uncover and maintain circulation to keystone advancement flaps in the lower extremities of ten individuals. Intraoperative thermograms correctly predicted 100% flap survival for 9 flaps and marginal ischemia for 1 flap, as shown in the research. Dehiscence occurred in the later flap that mended by secondary purpose, whereas the remainder healed uneventfully.[9]

Additionally, Pereira and Hallock looked at the feasibility of utilizing smartphone thermography to map local flap perforators in the lower extremities. Smartphone thermography was used to locate perforators, and the study found that all local perforator flaps were based on those. 82.1% of flaps (23 total) made it through the experiment with one hundred percent viability, as anticipated by the thermal digital picture. Five flaps were thought to have a little chance of survival, yet two made it through unscathed and the others needed just minimal tweaks to function normally again.[10]

Also, Hummelink and colleagues evaluated the potential of an affordable infrared thermal camera and software in the postoperative identification of failed free flaps. Three of the 16 flaps had arterial failure, and one had venous congestion, leading to failure. The most reliable predictor of flap failure was the variance in mean flap temperature between the flap and the neighboring control skin. All failed flaps had cooler temperatures after failure compared with intact free flaps, therefore they reasoned that the thermal camera module could have something to offer in the way of postoperative monitoring of free flaps.[11]

In addition, many noninvasive imaging modalities (Thermal, Hyperspectral, and Laser Doppler Imaging) were analyzed by Nischwitz and colleagues to determine their suitability for perforator location identification. With this research setup, sensitivity was demonstrated to be 94.44% for thermal imaging, 38.89% for hyperspectral imaging, and 0% for laser doppler.[12]

4.1. Conclusion

The thermal camera is a fast, simple, low-cost, and reliable way for detecting perforators in the lower leg, making it a valuable tool for mapping perforators in free-style perforator flaps design.

Conflicts of interest

There are no conflicts of interest.

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