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CASE REPORT

Reconstructive

Thermal Imaging in a Clinically Non-assessable Free Flap Reconstruction of the Face

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Summary: Free flap monitoring and early detection of malperfusion are a central aspect in reconstructive surgery. Warm ischemia, measured as the time a certain tissue is able to survive without any additional medical or thermal treatment, ranges from hours in muscle and nerval tissue up to days in bony tissue. Hence, meticulous flap monitoring is essential to discover early signs of malperfusion and decide upon timely re-intervention. Besides clinical examination techniques and Doppler sonography, a multitude of mostly experimental procedures are available to evaluate free flap perfusion. Particularly in older patients, the assessment of the skin island in microvascular grafts is a demanding task because the natural loss of elasticity, the reduction of subcutaneous tissue, and the decrease in water content limit the visibility of capillary filling and favor hematomas. We report a case of a 90-year-old woman with an extensive cutaneous squamous cell carcinoma of the right zygomatic and lateral orbital region without any locoregional or distant metastasis. Due to the resilient health status, we decided for a surgical approach with consecutive microvascular radial forearm flap reconstruction. On account of the difficult assessment of elderly skin after microvascular transplantation, we decided on additional flap monitoring by thermal heat imaging during the operation and aftercare. This case report discusses the successful application of thermal heat imaging in a clinical non-assessable free flap and discusses the application of dynamic infrared thermography as a monitoring tool in microvascular free flap surgery. *(Plast Reconstr Surg Glob Open 2021;9:e3440; doi: 10.1097/GOX.0000000000003440; Published online 17 February 2021.)*

Free flaps, with success rates of over 95%, have become a common procedure in reconstructive surgery.[1] However, even after complication-free surgery, transplants can show malperfusion, which commonly occurs within the first 48 hours after the operation and can lead to partial or even total transplant failure.[2,3] In dependence on the tissue, critical ischemia times vary from 4 to 6 hours for muscles and nerves up to 24 hours for the bone.[4] Therefore, flap monitoring is essential to detect circulatory disorders at an early stage and to decide on a surgical revision in time.

Besides the clinical evaluation, further monitoring techniques such as Doppler sonography or pin prick testing have been described.[5,6] However, especially in elderly patients, the assessment appears difficult because the skin is more vulnerable to hematoma, and skin folds are more prominent. Besides limitations in the clinical appearance, further assessment using Doppler sonography can provide consistent results on the function of the arterial pedicle, but the venous drainage is frequently not evaluable.

Thermal heat imaging (THI) is a non-invasive technique to face these shortcomings and was first described by plastic surgeons.[7] An infrared camera catches the radiation emitted by the scanned object and converts it into a visible image. As a rise in body temperature is usually caused by an increase in blood perfusion, the originating heatmap is used as a surrogate perfusion parameter and corresponds well to the clinical blood flow and vitality of the examined area. Previous work confirms the applicability of THI in burn depth assessment, perforator vessel detection, or the diagnosis of carpal tunnel syndrome and melanoma (Table 1).[8–11]

In the following report, we present a case of free flap monitoring of the facial skin in an elderly woman by THI,

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Table 1. Recommendations and Disadvantages for Thermal Heat Imaging as an Additional Diagnostic Tool

Recommendation for THI as an Additional Diagnostic Tool	Literature	Disadvantages of THI	Literature
Free flap monitoring and detection of vascular obstruction	Cruz-Segura A et al (2019). Early detection of vascular obstruction in microvascular flaps using a thermographic camera. *Journal of Reconstructive Microsurgery*. doi:10.1055/s-0039-1688749. Meyer A et al (2020). Thermal imaging for microvascular free tissue transfer monitoring: Feasibility study using a low cost, commercially available mobile phone imaging system. *Head & Neck*. John HE et al (2016). Clinical applications of dynamic infrared thermography in plastic surgery: a systematic review. *Gland Surgery* 5 (2):122. Tenorio X et al (2009). Early detection of flap failure using a new thermographic device. *Journal of Surgical Research* 151 (1):15–21.	Intraoral free flap monitoring	Meyer A et al. (2020). Thermal imaging for microvascular free tissue transfer monitoring: Feasibility study using a low-cost, commercially available mobile phone imaging system. *Head & Neck*. Authors' experience
Perforator vessel detection	Hardwicke JT et al (2016). Detection of perforators using smartphone thermal imaging. *Plastic and Reconstructive Surgery* 137 (1):39–41. Salmi A et al. (1995) Thermographic mapping of perforators and skin blood flow in the free transverse rectus abdominis musculocutaneous flap. *Annals of Plastic Surgery* 35 (2):159–164. De Weerd L et al. (2009) The value of dynamic infrared thermography (DIRT) in perforator selection and planning of free DIEP flaps. *Annals of Plastic Surgery* 63 (3):274–279 John HE et al (2016). Clinical applications of dynamic infrared thermography in plastic surgery: a systematic review. *Gland Surgery* 5 (2):122.	Differentiation between venous and arterial vessel obstruction.	John HE et al. (2016). Clinical applications of dynamic infrared thermography in plastic surgery: a systematic review. *Gland Surgery* 5 (2):122. Authors' experience
Detection of carpal tunnel syndrome	Herrick RT et al (1987). Thermography in the detection of carpal tunnel syndrome and other compressive neuropathies. *Journal of Hand Surgery* 12 (5):943–949. John HE et al (2016). Clinical applications of dynamic infrared thermography in plastic surgery: a systematic review. *Gland Surgery* 5 (2):122.	Usage in low and high ambient room temperature differences to monitor the same patient/ free flap	Authors' experience
Assessment of burn wounds	John HE et al (2016). Clinical applications of dynamic infrared thermography in plastic surgery: a systematic review. *Gland Surgery* 5 (2):122. Jaspers MEH et al (2017). The FLIR ONE thermal imager for the assessment of burn wounds: Reliability and validity study. *Burns* 43 (7):1516–1523. doi:10.1016/j.burns.2017.04.006. Xue EY et al (2018). Use of FLIR ONE smartphone thermography in burn wound assessment. *Annals of Plastic Surgery* 80 (4 Suppl 4):S236–S238.	Usage in patients with high catecholamine doses	Authors' experience
Assessment of peripheral perfusion in vascular patients	John HE et al (2016). Clinical applications of dynamic infrared thermography in plastic surgery: a systematic review. *Gland Surgery* 5 (2):122. Wallace GA et al (2018). The use of smart phone thermal imaging for assessment of peripheral perfusion in vascular patients. *Annals of Vascular Surgery* 47:157–161. doi:10.1016/j.avsg.2017.07.028.		
Melanoma detection	Maillard G et al (1969). Thermography of malignant melanoma. Preliminary report. *Dermatologica* 139 (5):353. John HE et al (2016). Clinical applications of dynamic infrared thermography in plastic surgery: a systematic review. *Gland Surgery* 5 (2):122.		

where the clinical assessment appeared to be impossible due to the poor conditions of the aged skin.

CASE REPORT

A 90-year-old woman presented with an extensive cutaneous squamous cell carcinoma of the right zygomatic and lateral orbital region (Fig. 1). The medical history stated an arterial hypertension, a kidney insufficiency, and presbycusis. The preoperative computed tomography showed an extensive tumor formation of the lateral cheek with affection of the zygomatic periosteum, but without metastasis. Due to her good general and mental health, we considered a surgical treatment approach to which the patient and her relatives agreed. The tumor resection, including a partial removal of the zygoma, the lateral orbital wall and a small part of the orbital floor, was performed under general anesthesia. A radial forearm flap was raised, and anastomosis was performed at the facial artery and vein, and at the external jugular vein. The patient was extubated after surgery and remained at the intensive care unit for cardiovascular monitoring during the night. The woman recovered quickly, and surgical

Fig. 1. Clinical situation at the initial presentation at the outpatient clinic.

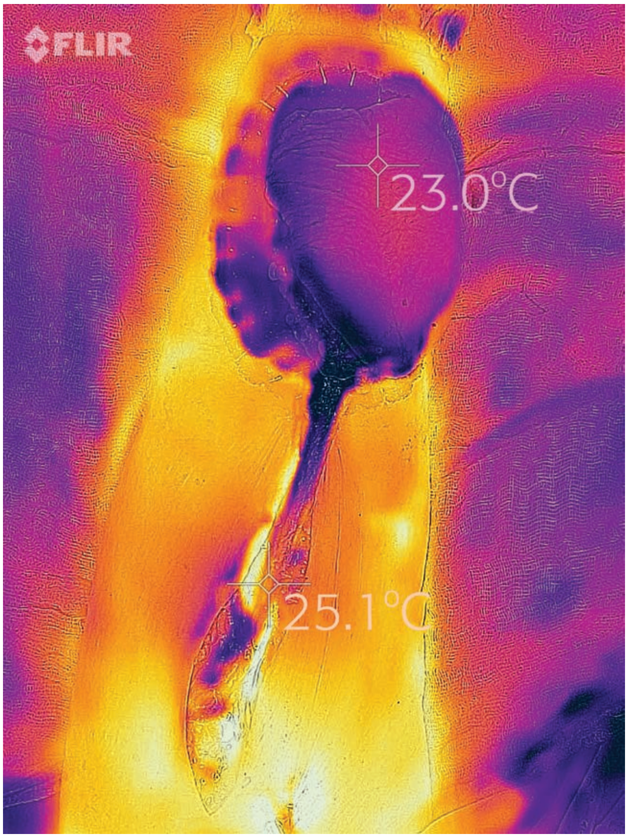

Fig. 2. Thermal heat image with a highly cooled down transplant after raising of the flap before dissecting the pedicle at the donor site.

aftercare remained uneventful. THI was performed by the use of a portable smart phone camera (FLIR One Pro, FLIR systems, Wilsonville, Ore.) before radial flap raising, intraoperatively (Fig. 2) and in surgical aftercare (Fig. 3) comparable to the protocols described by Meyer et al and Cruz-Segura et al, and evaluated a well-perfused, vital flap at all times.[12,13]

An ophthalmologic consultation confirmed a regular eye function and histopathological examination stated a pT3 L0 V0 Pn0 G3 R0 squamous cell carcinoma with an infiltration depth of 1.8 cm. The interdisciplinary tumor board recommended adjuvant radiotherapy, which was rejected by the patient, who is now in regular follow-up examinations (Fig. 4).

DISCUSSION

Constant demographic aging is a major concern in nowadays society and goes in line with the rising incidence of skin cancer. Non-melanoma skin cancer is the fifth most common cancer in humans and is predisposed to the sun-exposed skin of the head and neck.[14] According to the treatment guidelines for cutaneous squamous cell carcinoma, surgical R0 tumor resection is the first line therapy in operable cases.[15] However, with regard to the reduced physical strength of the elderly, compromises in treatment regimens need to be considered to ensure adequate tumor therapy but keep the patient integrated into their daily routine.[16] Nevertheless, recent publications determine microvascular procedures to be safe in elderlies after thoughtful patient selection with regard to their individual physical and mental resources.[17,18] Due to the limited clinical accessibility

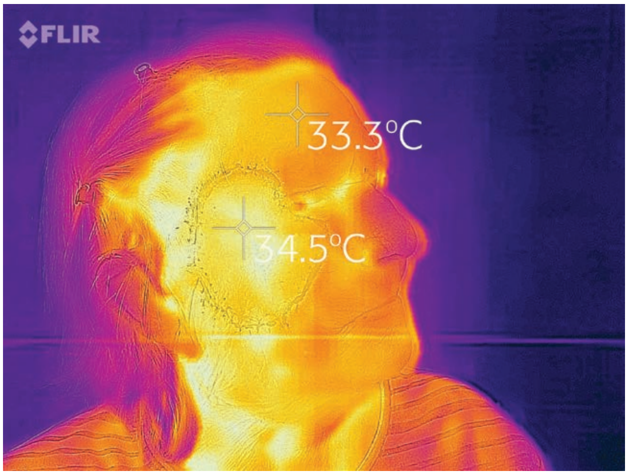

Fig. 3. Thermal heat image of the hyper-perfused, healed flap 10 days after surgery.

Fig. 4. Clinical situation at hospital discharge, 10 days after surgery.

of the frail elderly skin, which tends to develop sub- and intradermal hematoma and deep skin folds, we decided for additional flap monitoring by THI. THI was known more than half a century before it became an increasingly popular tool in reconstructive and burn surgery.[8,12,19] The FLIR One Pro camera applied in this case is a comparatively low-cost device (400€) that can be connected to a mobile phone or tablet and has been successfully described in earlier publications.[9] The infrared sensor (8–14 μm) detects temperatures between −20°C and 400°C and allows an image or video capture of the scanned object. In the presented case, we are able to show that initially during flap raise the transplant temperature drops about 9°C from 32.7°C to 23.0°C (Fig. 2). After reanastomosis of the flap to the recipient site, the temperature rises again, but remains about 5°C below the initial temperature. During follow-up THI, the flap develops signs of hyperperfusion with temperatures even 3°C above the initial degrees at the donor site, which may be seen as a result from the higher blood flow rate and pressure in the external carotid branches compared with the peripheral arteries of the forearm as well as a denervation sign of the smallest nerval branches accompanying the vessels and in line with a successful healing process (Fig. 3). (See **Video 1 [online],** which displays an example of a clinically non-assessable flap by spreading out the transplant with a spatula.) (See **Video 2 [online],** which provides information about the good flap perfusion and additionally spreading out the transplant with a spatula.)

CONCLUSIONS

THI is an especially useful tool in flap monitoring of the clinically non-assessable skin of the elderly patient. The temperature dynamics form the time before the flap raise up to surgical aftercare provide relevant information about the blood flow dynamics in microvascular transplants and will be assessed in further studies to offer a more detailed understanding of the rheological physiology in microsurgery.

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PATIENT CONSENT

The patient provided written consent for the use of her image.

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