Chapter

Identification of Body Contouring Surgery Complications by Multispectral RGB/Infrared Thermography Imaging

Marcos Leal Brioschi, Soane Couto Menezes Lemos, Carlos Dalmaso Neto, Franciele De Meneck, Patricia Rodrigues Resende and Eduardo Borba Neves

Abstract

Infrared thermography can assist in the documentation of inflammatory vascular healing reactions and tissue perfusion resulting from esthetic surgical procedures in different parts of the body and face. Both in preoperative planning and in its postoperative evolutionary behavior. Infrared thermography is a functional imaging technique of cutaneous vascular activity using long-infrared electromagnetic radiation emitted by tissue cells. It can accurately identify terminal cutaneous perforating vessels related to greater or lesser skin perfusion, non-invasively, quickly, painlessly, safely and without emission of ionizing radiation by scanning a segment or entire body in a single image. This facilitates the evaluation of patients undergoing lipoabdominoplasty and their postoperative follow-up. Monitoring of new techniques and traditional procedures with infrared scanning technology helps in the early diagnostic elucidation of complications (edema, seromas, epidermolysis, hematoma, dehiscence, infection, necrosis), evolutionary studies of healing and local effects of thermoguided procedures (such as manual therapy, laser photobiomodulation, ultrasound, radiofrequency, hyperbaric oxygen therapy) direct the treatment with more objectivity, better results, and safety.

Keywords: thermography, healing, abdominoplasty, postoperative complications, abdominal wall

1. Introduction

Physiologic risks of plastic surgical procedures are comparably less than those of other surgical subspecialties, as the procedures are typically elective, and usually performed in relatively healthy subjects. Most common postoperative complications include infections, local anesthetic systemic toxicity, electrolyte and hematologic abnormalities, intravascular fluid shifts, deep vein thrombosis, and wound complications (hematoma, ecchymosis, swelling, seroma, tissue edema, localized pain, nerve damage, infections, and cellulitis). In a lipoabdominoplasty systematic review 5.6% of wound infection, dehiscence, or fat necrosis; 4.1% of seroma; 0.8% hematoma; 0.2% deep venous thrombosis; and 0.7% scar deformity [1]. Studies on the use of thermography in the plastic surgery field are promising. Most of them verified the use of infrared thermography to assess perforating vessels' location and quality in the pre, intra- and postoperative period and concluded that the thermographic examination helps in planning the surgeries and more efficient results with a reduction in complications [2, 3].

So, it is important to review the literature regarding the use of infrared thermography, exposing how it works as a complementary functional bedside exam; and discussing what is known about the applicability of this method in abdominoplasty post-operatory complications.

2. Methods

2.1 Infrared imaging (thermography)

Infrared thermography is a non-invasive, non-contact, non-ionizing, functional imaging method for direct measurement of skin temperature surface and indirect measurement of skin perfusion, microcirculation, inflammation, metabolism, and sympathetic vasomotor nerve activity, providing a surface temperature distribution map. The assessment of skin perfusion through the identification of arterial-perforating vessels, with their location visible on thermography as skin "hot spots" [4] by thermography has been used in plastic surgery with good success. However, skin temperature and skin blood flow were not linearly correlated. While skin temperature can be used to study thermal physiology, it should not be considered a substitute for dermal blood flow.

The human body emits thermal radiation, and there is a correlation between the energy of the thermal radiation and the temperature of the skin. Infrared thermography is a method of remote scanning of the human body that identifies areas of greater or lesser brightness of infrared thermal radiation. According to the Stefan-Boltzmann law, the greater the radiation emitted by a body, the greater its temperature – $W = \varepsilon\sigma T^4$, where W is the rate of emission of infrared radiant energy (W/m^2), ε is the emissivity of the body (0.98 for the human body), σ is the Stefan-Boltzmann constant ($5.7 \times 10^{-8} Wm^{-2} K^{-4}$), and T the body temperature (K). To maintain its internal thermal homeostasis, the body exchanges heat with the environment (conduction, convection, evaporation). The energy emitted in the form of infrared radiation represents 60% of the total, with 80–90% doing so with a long wavelength of 8–15 μm when the person is exposed in a room at 23°C for 15 min. The thermal transducer can detect the infrared radiation emitted by the skin surface and generate an entire body surface thermal map image.

Skin temperature depends on the cutaneous and subcutaneous tissues' vascular supply and skin thermal conductivity as it is affected in different cutaneous pathological situations. Localized blood flow changes related to capillary system alterations can induce changes in skin temperature and therefore reveal skin inflammation, ischemic areas, or cellulite [5]. Consequently, monitoring skin temperature would provide information related to the blood flow throw the skin [6].

2.2 The perforating vessels thermal concept

The subcutaneous tissue contains small and medium-sized arteries, crossing the hypodermis in two ways: a) perpendicular, where the path crosses the fascial and subcutaneous layers to reach the skin (perforating arteries); b) longitudinal, the course where they cross the subcutaneous tissue in an oblique course following the superficial fascia for extensive lengths. Vessels follow, in subcutaneous layers, the retinacula – that provides protection to vessels and prevents their displacement when the skin is pulled –, to go perpendicularly from the deepest skin planes. Around the retinacula, the vessels have a tortuous path with many curves. So, when the skin is lifted, the vessels can stretch without damage.

The areas of greatest thermal leakage correspond to the exit sites of subcutaneous axial vessels called perforating vessels, that perfuse a certain cutaneous area (angiotome). 97% of the perforating cutaneous vessels observed on Doppler ultrasound coincide with thermal points presence (hot spots on thermography) [7]. Doppler ultrasound locates perforators at a deeper level, whereas thermography locates them more superficially (under the skin surface). As such, they showed that no cold challenge may be necessary. Blood vessel expansion, and consequent flow volume increase of these perforating vessels, are sympathetic neurovegetative nervous system controlled. So, poorly myelinated sympathetic fibers control the cutaneous perfusion of their corresponding dermatome/angiossome. Cutaneous microcirculation has a thermoregulatory function, being essential for steady body temperature maintenance. Although the volume of the capillaries is small, their surface area is large compared with other skin vessels.

Physiological regulation of cutaneous microcirculation includes sympathetic activation, which causes vasoconstriction. The sympathetic cholinergic system is mainly involved in vasodilation. Endothelium-dependent vasomotion implicates nitric oxide, prostacyclin, endothelium-dependent hyperpolarizing factors, and endothelin. Variations in skin blood flow result from highly complex interactions between these mechanisms, and perfusion assessment for the impaired cutaneous blood flow early detection may alert clinicians to microvascular changes as a marker of tissue viability. In certain situations, thermal stress can be performed to produce skin cooling and vasoconstriction and, subsequently, thermal images can be obtained during the cutaneous rewarming process using the perforating cutaneous vessels [2–4, 8]. Thermography reinforces the importance of performing local healing treatment at thermal points, rather than at an arbitrary location on the skin.

The manual or bioelectrical mechanical thermal point stimulation in a richly vascularized and innervated area explains much of the local and segmental effects of post-operative care procedures, by vascular activation, and by the peripheral sensory and sympathetic neurovegetative nervous system [9]. Infrared thermography permits evolutionary studies of healing and local effects of thermoguided procedures (manual therapy, laser photobiomodulation, ultrasound, radiofrequency, hyperbaric oxygen therapy [10–12]) near perforator vessels directing treatment with more objectivity, better results, and safety.

2.3 Bedside post-surgical thermography method

Patients must be instructed to not have a hot bath less than 2 h before assessment, not to use any topical substance on the skin, fastening for at least 3 h before the exam, and not to take stimulant substances (coffee, alcohol, cigarettes, etc.) 10 h before examination. An infrared thermography exam is usually performed 24 to 48 h postoperatively, before hospital discharge, and on the 5th, 25th, and 27th day after the operation. Captured thermal images are obtained using a double spectroscopy infrared-visual camera, 320x240 pixels image resolution, thermal sensitivity of 0.05°C and cutaneous emissivity set at 0.98, in a room with 23 ± 1°C controlled temperature, relative humidity less than 60%, and minimum air convection of 0.2 m/s. Patients rest comfortably, without abdomen covering clothes. First images should be taken 15 min after dressing removal, and captured at approximately 50 cm at straight angles. These images, in the double spectroscopy mode, are processed using specific color scales and oriented to a three-dimensional qualitative study using the Hypermax® function (**Figure 1C, F, I** and **L**; **Figure 2C**; **Figure 3C** and **F**; **Figure 4** and **Figure 5C, F** and **I**),

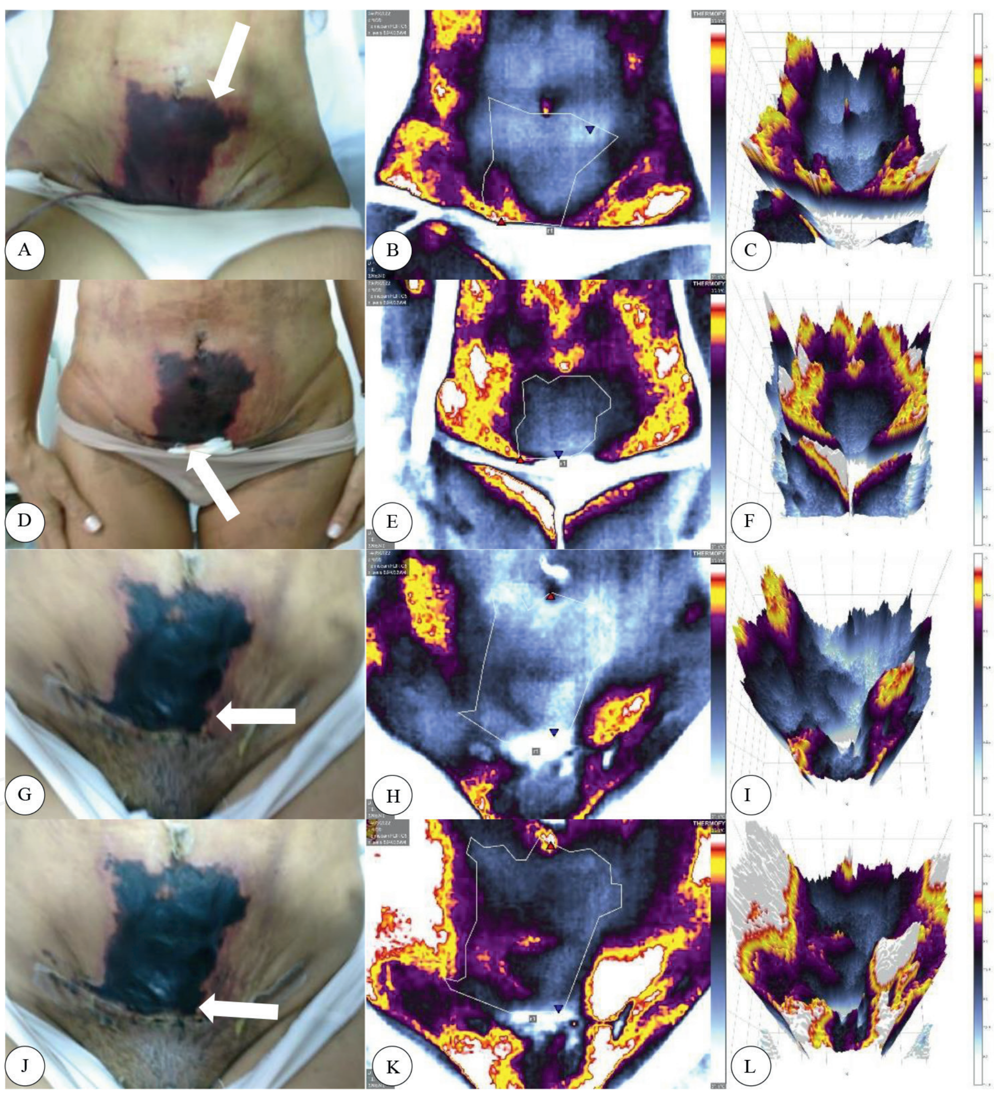

Figure 1.
Patient undergoing liposuction associated with mini-abdominoplasty and diastasis correction. On the 2nd POD progressed to infraumbilical pain and burning sensation, and the strap was removed. An area of possible tissue suffering was observed (B-C). Immediate indications for hyperbaric and ozone therapy to delimit the area and surrounding tissue oxygenation. Thermographic follow-up on subsequent days maintenance of daily hyperbaric therapy and ozone therapy on alternate days (via bag) in the abdominal region. On the 7th POD, showing delimited epidermolysis and central necrosis (D-F). On 12th POD, a change in the tissue appearance (G) (carapace more rigid in the lower third) evolving with dehiscence in the scar area, with correspondent hyporadiation (H-I). Initial option of autolytic debridement and special dressings (vacuum) to prepare for future corrective surgical intervention. Hyporadiation area (K-L) smaller than before (B).

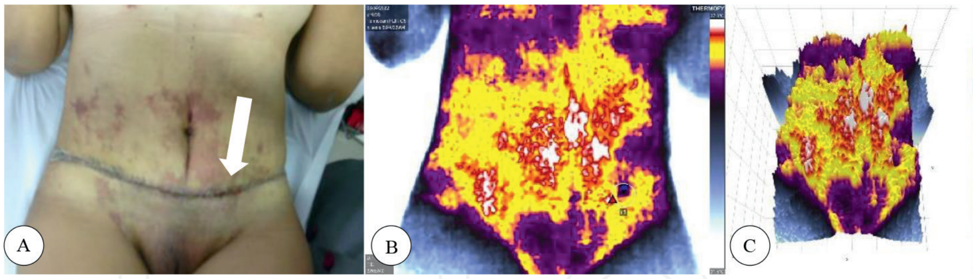

Figure 2.
Another patient undergoing lipoabdominoplasty, with diastasis correction on the 5th POD, with ecchymosis areas (burn, hemosiderin deposition), without signs of pain or local burning. Thermographic imaging (A) helped in the conservative management choice in the abdomen, and therapy in a small hyporadiant cold area at the scar (left iliac fossa) (B). After removal of the surgical glue, the patient presented with an intact scar, and the skin evolved only with brownish spots.

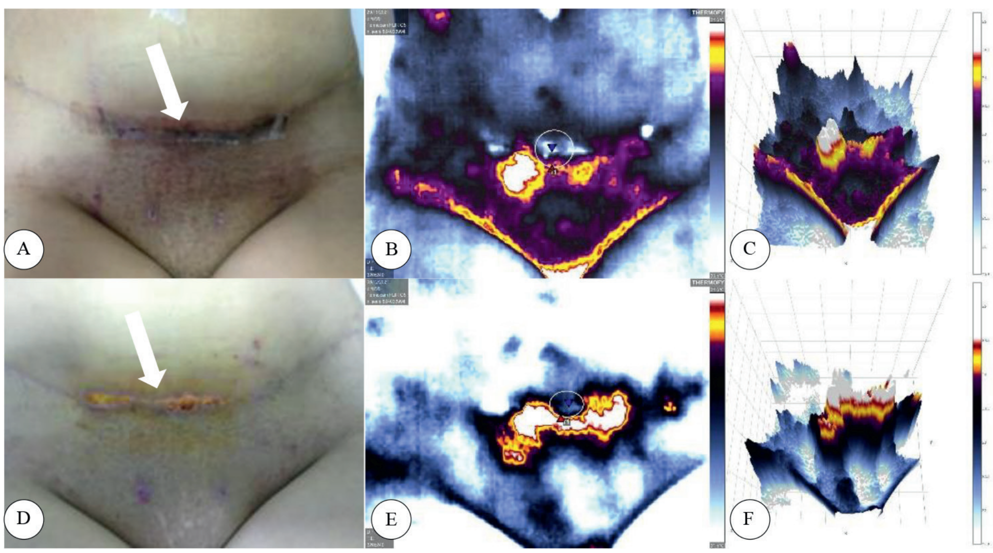

Figure 3.
Patient on the 8th POD of reduction mammoplasty and abdominoplasty scar correction performed 1 month early. When using surgical glue, it is possible to identify cold-hyporadiating areas (A, B, and C), with possible dehiscence. Tissue repair therapy with photobiomodulation, manual therapy, and local ozone therapy was started (D, E and F), 2 days after the first images.

and quantitative study using automated tables and graphs of authors developed specific software (VisionFy®, Thermofy, Brazil).

With the development and greater precision of infrared transducers, it is now possible to combine them with automatic evaluation through medical analysis software and obtain automatic recording in real-time, with high precision, establishing the continuous dynamics of certain thermal points, and the immediate and late effect of local post-surgical healing treatment.

The image analysis process extracts parameters describing the overall skin temperature (median T°; T° amplitude), the homogeneity of the temperature (Sa, Sz, Sq), and the visual contrast between hot and cold areas on the images (number and surface of cold and hot areas). Standard roughness parameters (Ra, Rz, Rq) are extracted from these images to capture the changes in skin temperature homogeneity – Roughness Average (Ra) is the arithmetic average of the absolute profile heights T values over the evaluation length; Average Maximum Height of the Profile (Rz) is the T average of the successive values of RT_i calculated over the evaluation length.

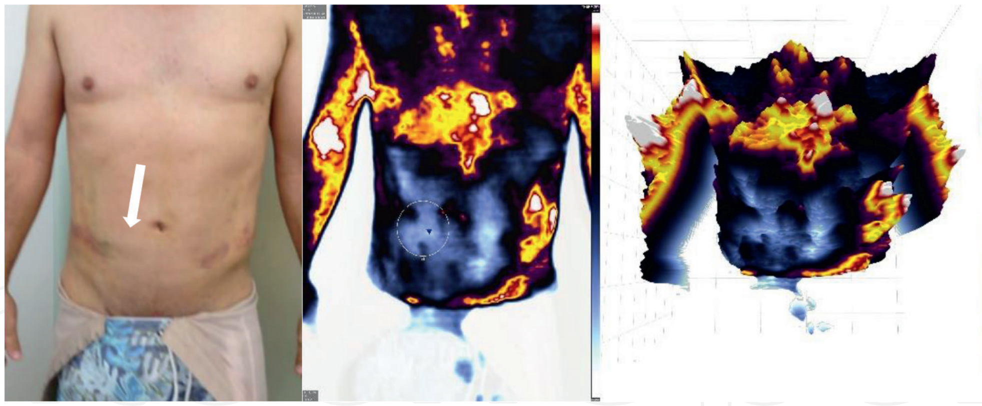

Figure 4.
Patient in the first week of high-definition liposuction, presented with hyporadiant area in the right flank and iliac fossa, with seroma-suggestive signs. No pain or other inflammatory signs.

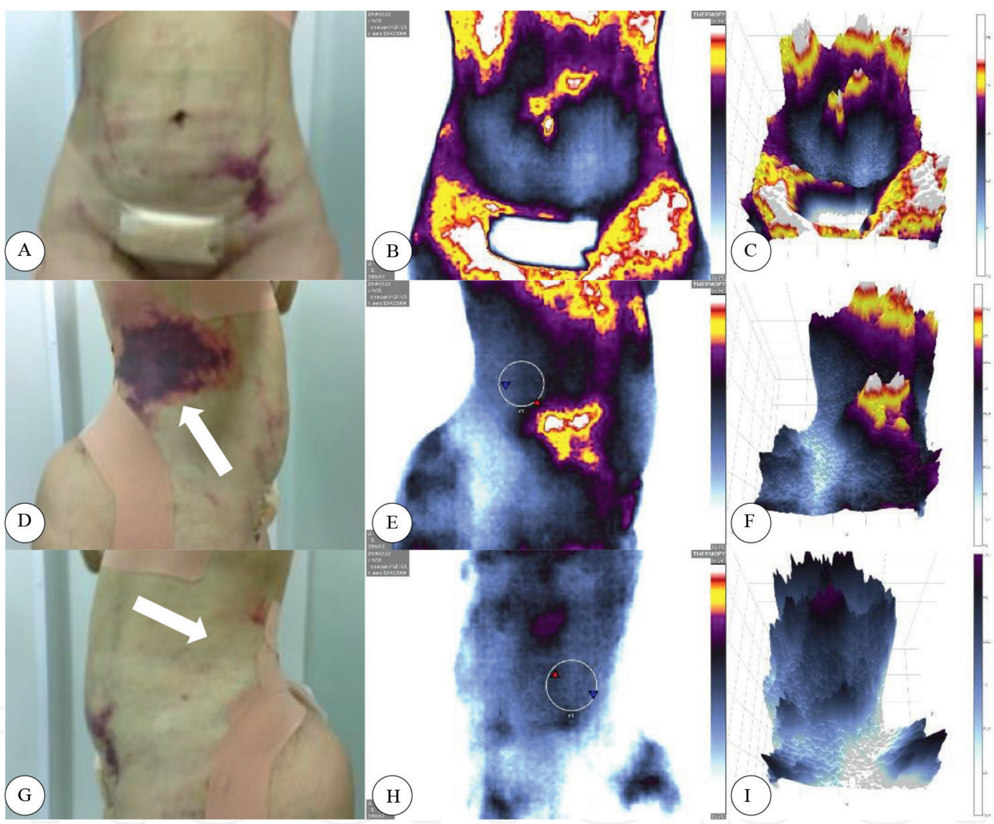

Figure 5.
Patient on the 5th POD of definition liposuction, using a device to promote skin retraction. Started hyperbaric therapy on the 1st POD. A-C, showing the frontal view, D-F right view, and G-I left view. The iliac fossa area evolved only with hypercromia, without necrosis and tissue loss. Area of intense ecchymosis (showed in D), evolved later to an area already identified with necrosis (past 11th POD). The left area evolved only with hyperchromia, with no signs of necrosis and tissue loss.

RMS Roughness (Rq) is the profile height T root mean square average over the evaluation length. The scale proposed in the literature evolves from a uniform hot skin to a "leopard" pattern skin and finally to a uniform cold skin. Thus, the overall skin temperature and homogeneity are related to skin complications.

For thermal image analysis, in the case of lipoabdominoplasy, Huger zones, reviewed by Matarasso [13], can be used as a region of interest (ROI) reference, which considers the anterior abdominal wall vascular anatomy and that region's blood supply.

The ROI SA3 (caution) was chosen, where two ROIs were determined in this area: ROI_1, at the highest point (supra umbilical); and ROI_2, at the lowest point above the suture, due to random and axial blood supply to the abdomen. To assess complications risk due to ischemia or tissue inflammation the values of the delta-R (ΔT_R), and difference in minimum ROI_1 temperature with minimum ROI_2 temperature were calculated.

3. Results

3.1 Hyperradiant areas (inflammation, infection)

Resende et al. [14] published the results of two clinical cases with thermal imaging monitoring of lipoabdominoplasty healing process, in the immediate postoperative evaluation, using the delta-R methodology: 1) ΔT_R = 0.4°C on 1st postoperative date (POD), decreasing to 0.1°C on 5th POD, without complications; and 2) ΔT_R = 1.7°C on 1st POD, remained high (ΔT_R = 2.2°C) on 5th POD (evolving to surgical scar necrosis). ΔT_R thermal index may be a new tool for predicting possible complications, complementing the clinical evaluation, and therapeutic decision-making was the conclusion.

Cicatricial complications in Plastic Surgery can arise from blood stagnation (thermographically represented by greater energy leakage), which can be generated by a local, systemic etiological factor, or a combination of these. In tissue ischemia, there is a decrease in tissue perfusion and local oxygen diffusion, causing a deficiency of elements responsible for cellular mitochondrial metabolism, and the typical sensation of discomfort, heaviness, or pain. This blockage can be aggravated by bad positioned external compressive factors presence (compression mesh and abdominal splints) or local infectious factors that prolong and accentuate the process. More than 90% of O_2 consumption in humans is due to mitochondrial metabolism, which is used to generate ATP, which fuels cellular processes such as during wound healing, and generates tissue repair energy, which consequently leads to a hypermetabolic state. About 55% of the energy is lost as heat, the rest in enzymatic-cell reactions. Every time the chemical energy contained in ATP molecules is transferred to the functional systems of cells, more energy is dissipated as heat. Also, ATP induces endothelium-dependent vasodilation. Acute inflammation following the injury process (NADPH oxidases and nitric-oxide synthases related) also produces more heat. Therefore, skin temperature increase in the initial healing process is normal and expected.

Therapeutic post-surgical techniques consist of manual and physical means of application on the body surface, to restore tissue healing, energy balance of this system, and promote remission of post-operative symptoms, and thermography has been used in the therapeutic application of plastic surgery, diagnosis, and selection of cutaneous perforating vascular points to being closely stimulated, as well as for real-time assessment of the immediate effects produced by patient's rehabilitation intervention and reassessment. There is a temperature gradient between the thermal spot location and the surrounding tissue, that is, there is a significant thermal difference between the location of the spot and the neighboring tissue [15].

3.2 Hyporadiant areas (swelling, seroma, epidermolysis, hematoma, necrosis, dehiscence, fibrosis)

Normal abdominal surface infrared emission usually has a mottled pattern of heat gradations, normally varying about 1°C. In the central region, there is a hot spot caused by the depression imprinted by the umbilicus cross-radiation. The underlying areas of fat are good insulators and tend to decrease skin temperature as they become thicker. Places of blood accumulation, such as bruises or very inflamed skin, raise the skin temperature locally. In contrast, benign processes, and other regions of low metabolic activity, such as hair, seromas, epidermolysis, ecchymosis, gangrene, dehiscence, and necrotic tissue, are hyporadiant (**Figure 1B, E, H**, and **K**; **Figure 2B** and **E**).

Temperature differences between wound and reference skin territories could provide a possible infection risk thermal "signature", with "cold spots" proposed as a marker of an "avascular" region along the incision site [16]. The maximum temperature difference between healthy reference abdominal skin and wound site exceeds 2°C in developing surgical site infection (SSI) suspects. 1°C reduction in abdominal temperature led to a 3-fold raised odds of infection. A 1°C temperature widening between ROI_2–ROI_1 (wound minus abdomen) was associated with an odds ratio for SSI of 2.25 (on day 2) and 2.5 (on day 7) [17]. "Cold spots", due to a reduction in cutaneous blood flow, were observed along the scar from day 2 in many women who later developed SSI (wound being observed "hotter" than the abdomen on the thermal image).

Cutaneous necrosis in abdominoplasty can be presented visually simply, as signs of self-limited epidermolysis and small dehiscence until extensive necrosis with loss of substances in deep planes [13]. In the immediate postoperative period, the expected physiological effect is an increase in blood flow, with a consequent increase in temperature, the inflammatory process inherent to tissue healing. The normally expected drop in the wound infrared emission occurs 1 to 3 days before the rapid increase in tensile strength. Temperature peak coincides with the increase in mucopolysaccharides in the scar (**Figure 3A** and **D**), an essential component for collagen formation. A decrease in infrared emission is associated with the "collagen phase" of wound healing. In the case of infection or wound dehiscence, there is a prolongation or plateau of infrared emission, indicating a delay in healing.

It is possible to use thermal imaging to detect accentuated hyporadiation, as observed in **Figure 3** and, consequently, a situation of decreased perfusion is much more sensitive than visual or tactile clinical evaluation. Only the central area progressed to superficial necrosis, which justified maintenance of conservative care (bandages) without surgical intervention (different from **Figure 1** case). There is always the possibility of reducing blood flow in the region surrounding the surgical incision, with consequent impairment of oxygenation and nutrients delivery to the wound, so the authors suggest calculating the delta-R (ΔT_R) in SA3 region using the minimum temperature between ROIs 1 and 2, as between these areas the main angiosomes and perforating vessels responsible for the nutrition of the flap (critical area) are located [13]. In any surgery, there is a possibility of reducing blood flow in the specific region to the surgical incision, with consequent impairment in oxygenation and delivery of nutrients to the wound. The importance of checking reference values for normal and pathological deltas (such as ΔT_R) in early monitoring of the healing process in plastic surgery is emphasized to serve as safer parameters for early decision-making.

Subcutaneous fat may be related to postoperative wound complications. Abdominal subcutaneous tissue thickness represents a significant risk factor for infection in the abdominal wound incision region [18]. Using the gold standard Dual-Energy X-Ray Absorptiometry (DXA) and bioelectrical impedance with infrared thermography [19, 20], women exhibit lower values of surface temperature than males on the abdomen, which was related to a higher body fat percentage in this gender. Higher body fat percentages are related to lower skin surface temperature in the abdomen. It appears to be a greater risk of infectious complications in the cooler abdominal wall, in women.

The adipose tissue affects heat emission processes in obese women because the skin microcirculation is impaired in these areas (vessels <150 μm in diameter). Larger fat lobes decrease local vascularity. In the large-deposit white adipose tissue, essentially peri-umbilical, cells are concentrated and linked by a weak net of collagen fibers. Collagenic components are very poor, cells are large (95 μm) and few blood vessels are present. There is a structural absence of capillaries and arterioles, and the microcirculation is formed by thin-walled capillaries with rare stem niches [21]. The subcutaneous region also includes the venous plexus which strongly influences skin temperature. Poorly vascularized areas of those rich in fat tissue have a lower temperature.

We observed that the seroma and hematoma presence are usually hyporadiating in thermal images (**Figure 4**), and have a more diffuse distribution, not limited to the anatomical area and the angiosomes of that region (**Figures 4** and **5**). Greater differences in temperature (ΔT_R) may suggest, in addition to the impairment of microcirculation and metabolic tissue activity, more serious complications are, and worse the prognosis. In lipoabdominoplasty postoperative period, hyporadiating areas were related to microcirculatory complications (hematomas and seromas). Greater temperature differences in the caution area may suggest necrosis. It is recommended to avoid excessive liposuction, closure under tension, and very tight compressive meshes use, to reduce the risk of ischemia [1, 22]. Similarly, edema formation and liquid stasis in the extravascular spaces should be avoided (as they can lead to the plugging of small local vessels) [23]. It is important to remark that the meshes fold in the abdomen midline, regardless of the type of compressive mesh used; these folds can exert greater pressure on the midline of the abdomen and can decrease blood flow [13].

Long arteries are usually connected by long anastomoses, which form longitudinal arches arranged in the deep subcutaneous fat tissue. All the capillaries of the fat lobules originate from these oblique arteries. Subcutaneous tissue is arranged in anatomical units or compartments, and each anatomical compartment is associated with an identifiable artery and vein [24]. These compartments could correspond to the abdominal quadrants, and the specific organization of the superficial fascia and retinaculum cutis defines the subcutaneous compartments, and the distribution of these vessels.

All subcutaneous arteries participate in the formation of two freely communicating subcutaneous plexuses: the subpapillary plexus, just below the papillary dermis; and the deep plexus, within the superficial fascia. Only one-fifth of the capillaries are needed for skin vascularization, while the others involve thermoregulation function. The deep plexus arteries have many arteriovenous connections, that provide shunts that control blood flow to the skin and, consequently, regulate body temperature. Dilation and narrowing of subcutaneous arteries determine skin temperature and color. The marked pallor of the skin seen in acute shock is a result of the vasoconstriction of the arterial plexus in the hypodermis. It can be assumed that a fibrotic superficial fascia over time could suffocate the arteries within it, thus changing skin color or even chronic skin ischemia. Chronic ischemia can increase subcutaneous fibrosis, creating a vicious circle, and persistent cutaneous cooling, with a well-defined local hyporadiation. If arteriovenous shunts become deficient, thermoregulation change may occur, thus resulting in sensations of excessively hot or cold skin.

4. Discussion

A selection of healthy thermal points for therapeutic treatment with thermographic support, compared with the conventional blind treatment, without the use of thermography in the postoperative abdominoplasty period, was examinate. The thermo-assisted group had a reduced number of sessions, complications, and shorter treatment duration in our experience. Additionally, studies have been conducted in which the diagnosis is obtained according to the symptoms and thermographic images in the patient's pain area. Based on this assessment, selected points distant from the patient's pain area were selected for the local heat treatment application, while using thermal imaging, to objectively observe the temperature modulation, with a rise between 0.5°C and 2°C in the cold symptomatic area and decrease in the inflammatory, coinciding with pain relief (**Figures 1**–**5**).

Recently, other non-invasive means have shown promise for treating postoperative complications as they do not cause pain and increase local microcirculation with increased temperature when applied to thermal points. Thermal imaging ROI showed that additional stimulation with a multimodal infrared light-emitting diode (IR-LED) pad (700 nm to 1000 nm range) caused 113% increase in temperature, compared to stimulation without IR-LED. Photobiomodulation had significant effects on cutaneous vascular stimulation.

Infrared thermography can be the key to identifying specifically the main limitations of a given wound, by evaluating its vascular tone. For example, the supply of oxygen and nutrients to the wound bed is provided by adequate blood flow to the healing site, whereas hypoxia delays healing. Reduced blood flow in the surrounding wound incision region causes a disbalance in oxygen and nutrients delivery to the wound, adding slow wound healing risk, or infection, by creating areas of skin commensurate with "low-perfusion". Wound pO_2 correction alone can trigger healing responses such as vascular endothelial growth factor expression, angiogenesis, and fibroblast stimulation, as optimizing wound perfusion provides supplemental O_2 that reduces the incidence of postoperative infections [25].

Chronic ischemic wounds are essentially hypoxic, which is incompatible with tissue repair. Among the causes that can decrease the temperature at the lipoabdominoplasty site, and cause moderate-to-mild hypoxia, is a sympathetic response to pain, hypothermia, and anemia, caused by major blood loss. Tissue at the near-anoxic sites will be vulnerable to necrosis, that in turn may propagate secondary tissue damage and infection. These areas of low perfusion and oxygenation, vascular "dead-space" region, possibly due to seroma or edema, may be heterogeneously distributed in the surgical site, creating true pockets with different levels of hypoxia. It is important to identify these cold spots through thermography as irregular cold "islands" distributed throughout the abdomen; and to thermally compare these areas with normal areas, as located within a higher average temperature, and blood flow, wound region, by averaging the temperature values.

Analyzing the extent and number of "islands" of low temperature within the wound, with the contribution of the adjacent healthy abdominal temperature, will improve the early identification of tissue complications. By mapping the abdominal wall skin temperature using thermal imaging, the aim is to assess the subtle changes in wound skin perfusion/oxygenation, and adjacent tissues, in the first days after surgery. The objective is to anticipate the signs and symptoms regarding post-surgical complications of infectious or non-infectious origin. There is still a lot to study about how to prevent post-plastic surgery complications. Measuring skin temperature by thermography to assess wound blood flow, and adjacent thermal territories, has the potential, as a non-invasive, independent imaging option, to identify "at risk" tissue. "Hot" or "cold" skin spot identification, proportional to regions of high or low blood flow/hypoxia, has the potential to shed light on the underlying mechanisms that lead to infectious and non-infectious wound complications.

The knowledge of the relationship between emitted long-wave thermal radiation, skin temperature, and blood flow in the abdominal incision region can offer a practical bedside functional imaging solution to broaden assessment criteria for wound prognosis from the visible spectrum to the infrared region.

Observing the wound map in "infrared", and measuring the temperature of the abdominal territories, offers a new perspective on wound assessment with an easy-to-perform technique as a complementary propaedeutic approach to exploring cutaneous microcirculation/hypoxia. Therefore, the authors of this study believe that surgeons and researchers consider the use of infrared thermography in post-operative abdominoplasty, to study the healing tissue and, if thermally identified, perform early intervention to avoid major complications.

Conflict of interests

All authors declare that they have no conflicts of interest.

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