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Maria João Neto de Almeida

Applications of Medical Thermography in Plastic Surgery – what has been done and future perspectives

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Maria João Neto de Almeida

Applications of Medical Thermography in Plastic Surgery – what has been done and future perspectives

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Dra. Rita Valença Filipe Ribeiro da Silva

E sob a Coorientação de:

Eng. Ana Carolina dos Santos Ribeiro Magalhães

Doutor Ricardo José Moreira Horta Oliveira

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NOME

Maria João Neto de Almeida

NÚMERO DE ESTUDANTE	E-MAIL
201504478	mj_almeida14@icloud.com

DESIGNAÇÃO DA ÁREA DO PROJECTO

Cirurgia Plástica

TÍTULO DISSERTAÇÃO/MONOGRAFIA (riscar o que não interessa)

Applications of Medical Thermography in Plastic Surgery – What has been done and Future Perspectives

ORIENTADOR

Rita Valença Filipe Ribeiro da Silva

COORIENTADOR (se aplicável)

Ana Carolina dos Santos Ribeiro Magalhães Ricardo José Moreira Horta Oliveira

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Applications of Medical Thermography in Plastic Surgery – What has been done and Future Perspectives

Aplicações da Termografia Médica em Cirurgia Plástica – O que já foi feito e Futuras Perspectivas

Maria Almeida[1], Carolina Magalhães[2], Ricardo Horta[1,3], Rita Valença-Filipe[1,4,*]

[1] Faculdade de Medicina da Universidade do Porto, Alameda Prof. Hernâni Monteiro, 4200- 319 Porto, Portugal.
[2] LABIOMEP, INEGI-LAETA, Faculdade de Engenharia, Universidade do Porto, Porto, Portugal
[3] Serviço de Cirurgia Plástica, Reconstrutiva, Estética e Unidade de Queimados, Centro Hospitalar Universitário de São João, Porto, Portugal.
[4] Serviço de Cirurgia Plástica e Reconstrutiva, IPO Porto, Porto, Portugal

*Correspondence: Rita Valença-Filipe, E-mail: ritavfplastica@gmail.com
Rita Valença Filipe Ribeiro da Silva
Rua de Grijó nº48 5º direito, 4150-384 Porto, Portugal

Applications of Medical Thermography in Plastic Surgery – What has been done and Future Perspectives

Resumo

Introdução A Termografia Médica, dotada da capacidade de avaliar de forma não invasiva a termorregulação tecidular, confere a possibilidade de construir uma imagem corporal, permitindo fazer inferências sobre processos fisiológicos e patológicos que se desenvolvem à sua superfície ou que tenham tradução nela. As suas aplicações em Cirurgia Plástica são muito diversas, estando neste artigo sumariadas algumas áreas onde esta técnica tem conquistado uma atenção crescente.

Métodos Foi realizada uma pesquisa na literatura via PubMed em setembro de 2020, bem como uma breve revisão nas referências dos estudos incluídos, a fim de encontrar outras citações relevantes. A estratégia de pesquisa foi sensível aos resumos e corpo de texto, usando a seguinte *query*: "((thermography) and (plastic surgery)) and ((burns) or (skin lesions) or (flap surgery))".

Resultados A presente revisão da literatura demonstrou as aplicações da Termografia Médica em Cirurgia Plástica, mais concretamente no âmbito do diagnóstico de lesões cutâneas de malignidade incerta, na avaliação da profundidade de queimaduras e, finalmente, na seleção pré-operatória de perfurantes para retalhos livres em reconstrução mamária e na sua monitorização intra e pós-operatória.

Conclusão A Termografia moderna é, atualmente, um método não-invasivo, credível e útil na prática clínica de Cirurgia Plástica.

Abstract

Introduction Medical Thermography, provided with the ability to non-invasively assess tissue thermoregulation, gives the possibility to create a body image, allowing inferences to be made about physiological and pathological processes that develop on skin surface. Its applications in Plastic Surgery are broad, being some areas where this technique has gained increasing attention summarized in this paper.

Methods A literature search on PubMed was conducted in September 2020, as well as a scan of the included studies' reference lists in order to search for additional relevant citations.

The search strategy was sensitive to texts and abstracts, using the following query: “((thermography) and (plastic surgery)) and ((burns) or (skin lesions) or (flap surgery))”.

Results The present literature review displayed the applications of medical thermography in Plastic Surgery, more specifically in the context of the diagnosis of skin lesions of uncertain malignancy, in the assessment of burn depth and, finally, in the preoperative selection of perforators for free flaps in breast reconstruction and its intra and postoperative monitoring.

Conclusion Modern Thermography is now a reliable, valuable non-invasive tool in Plastic Surgery clinical practice.

Key Words: Thermography; Plastic Surgery; Skin Lesions; Burns; Flap surgery; Breast Reconstruction.

Introduction

Plastic surgery is one of the most diversified specialties within the medical field, addressing patients integrally and intervening in a broader and comprising way. Its principles are to reshape, remold and manipulate both soft and hard tissues to ultimately repair form and function in an aesthetic fashion [1].

Despite constant progress in each medical specialty, technological development is always present, allowing refinement of diagnostic, monitoring, and treatment methods, which are becoming more precise, easy to use and less invasive.

Thermography is a successful example of technological progress, with a dramatic technology advance in thermal equipment over the last 25 years, accompanied by a revival of interest for its application on medical grounds.

Thermal imaging is a non-invasive and innocuous sensing method that uses thermal cameras to record infrared radiation emitted by the skin.

Observed thermal pattern relate, among many others, to body physiologic mechanisms of thermoregulation, local metabolic processes and structure and dynamics of vascular system.

This makes the method both image-forming and quantitative, offering, at last, the possibility of objective comparisons.

However, to understand information retrieved from thermographic images, it is essential to possess a comprehensive knowledge of body's thermal physiology. Besides, it is also noteworthy to recognize disturbances of thermal equilibrium, taking place when a physiological abnormality occurs (skin tumor, burn, inflammation, etc.), as they grant doctors, potential different diagnosis.

Thermography can be implemented either as a static (SIRT) or a dynamic (DIRT) imaging method.

SIRT quantifies radiation emitted without any temperature manipulation and requires attainment of a thermal steady state. In the end, analysis of static thermograms rests on the construction of temperature profiles representative of pathological processes underneath, being the difference in temperature (ΔT) the quantitative measure of interest, rather than absolute temperature.

This method can be time consuming and challenging, as steady state can be hard to attain, thus not allowing exclusive detection of variations caused by pathological states. Therefore, standardization in image acquisition still remains an objection in passive implementation [2].

In dynamic imaging, image acquisition follows the application of an external stimulus (chemical/ thermal/mechanical), performed to induce/enhance relevant thermal contrasts between investigated lesion and surrounding healthy skin [3], portraying a higher diagnostic accuracy and making it stand as a more robust approach [2, 4].

The present paper is an attempt to summarize the applications of thermography in some Plastic Surgery fields, as well as the needs and challenges in developing reliable diagnostic and monitoring tools for skin lesions, burn injuries and perforator selection in breast reconstruction surgeries, having thermography a growing interest on each of these grounds. The importance of this paper lies on the fact that thermography, with its aforementioned advantages, may actually be an image method that can revolutionize some of the areas of Plastic Surgery, where there are currently some gaps in terms of diagnostic and monitoring methods.

Methods

Eligibility criteria

Articles included were related to Plastic Surgery and Thermography applications with aforementioned endpoints.

Language restriction was set for English or Portuguese studies. No timeline restrictions were set.

Types of participants

No restrictions were made in participants included in studies.

Study selection

Literature search on PubMed was conducted in September 2020, as well as a backward citation in order to search for additional relevant citations.

Search strategy was sensitive to texts and abstracts, using the following query: "((thermography) and (plastic surgery)) and ((burns) or (skin lesions) or (flap surgery))".

For eligibility assessment, sequentially screening was made by scanning title and abstract, excluding majority of the studies. Further exclusion was made when remaining full text studies were read.

Results

Electronic search using the prescribed criteria revealed 89 studies. Backward citation led to the inclusion of 34 articles, and another 11 were added through experts' recommendation. After full text reading, 9 articles were excluded, as they did not approach thermography in Plastic Surgery, or were of little clinical relevance *(Fig.1).*

This article is further divided into thermography applications in skin lesions, burns and breast reconstruction. Other current applications of thermography and its future perspectives are also mentioned.

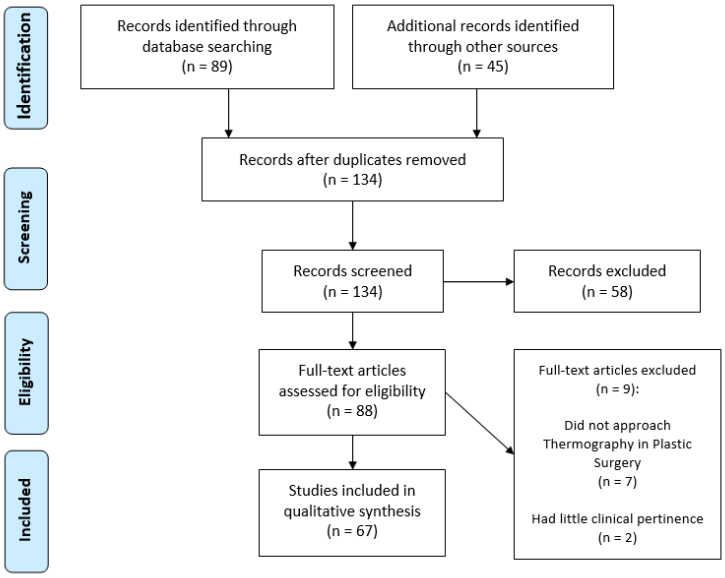

Figure 1 - Results of search strategy - PRISMA flow diagram [6]

Tumors and Skin lesions

Over the last years, skin cancer (SC) incidence has risen to a worrying level, mainly as result of excessive exposure to UV radiation.

The most common type of SC is basal cell carcinoma (BCC), which, despite rarely fatal, can be disfiguring. Squamous cell carcinoma (SCC), the second most common, has higher invasiveness potential but still highly curable. Melanoma, although accounting for less than 5% of SC, is responsible for most SC deaths (approximately 75%) [6, 7].

Most melanoma lesions arise from preexisting pigmentated lesions as superficial tumors confined to epidermis. During its horizontal growth phase, melanoma is potentially curable by surgical excision. Contrarily, melanomas that infiltrate into dermis are in a “vertical” growth phase and already have metastatic potential, strongly predicted by the tumor’s thickness–Breslow depth.

According to clinical reports, 5-year survival rate for patients with melanoma is about 99%, if detection occurs in early stages. However, 5-year survival rate drops dramatically to 15% if patient presents an advanced course of disease [8].

Nowadays, there are no systemic treatments that significantly extend life span for advanced stage patients [9]. The only effective treatment is early surgical excision. Thus, early detection and proper surgical treatment is the key to expand survival. To do so, it is essential to stablish a precise and confident diagnosis [10].

Traditionally, detection of melanoma lesions consists in visual examination using the subjective ABCDE criteria. Although method’s diagnostic accuracy achieves satisfying significance when used by trained practitioners, it only provides qualitative guidelines for melanoma identification. Moreover, it also yields high rates of false positives (specificity: 56%-65%) and frequent false negatives (sensitivity: 47%-89%). [11]

Detecting melanoma with human eye can be very challenging, not only because of diversity of possible presentations, but also due to the fact that melanoma often mimics benign melanocytic nevi (MN) *(Fig.2).*

Ultimately, to avoid risk of missing early-stage melanoma, excisional biopsies are routinely performed. However, these can cause unnecessary pain and discomfort, when dealing with benign tumors [7]. Furthermore, such technique can be time consuming and lead to unbearable waiting lists.

Thus, it is of great importance to study alternative diagnosis methods, that could capture and quantify information not readily available to the human eye while avoiding the intrusiveness of excisional biopsy [2].

Thermography has gained an increasingly value over the last decades, with a growing number of researchers studying its use in skin neoplasms.

Melanoma lesions are known to be warmer than surrounding healthy skin [12], due to their higher level of metabolism as well as augmented blood supply to support tumor's growth [13].

Since thermography takes advantage of tumor's vascular response to create thermal patterns, monitoring surface temperature should allow detection of suspicious warmer regions, which are highly connected to melanoma development [14]

Consequent differences in temperature encountered between leased areas and surrounding skin convey valuable physiological and pathophysiological information, having the potential to non-invasively differentiate malign from benign skin neoplasms [15-18], achieving sensitivity and specificity values of 95% and >80% respectively [15]

Three very important conclusions were reached: (1) benign pigmented lesions and healthy skin have similar thermal responses, so healthy skin can be used as reference when diagnosing cancerous skin lesions; (2) raised nevus behave differently than nevi flushed with the skin, presenting a colder region at lesion's center (highlighting the importance of taking lesion shapes in consideration); (3) temperature differences detected may scale with lesion' malignant potential - the deeper the level of anatomical invasion, the warmer the region and more noticeable malignancy, which ultimately could contribute for the development of a quantitative scale for decision-making criteria [6].

It was denoted that, in general, malignant lesions, such as melanoma and SCC *(Fig. 2),* are characterized by hyperthermic patterns (their thermal recovery is very short, giving the image of "hot" spot), while benign ones such as seborrheic warts, cysts, or even BCC *(Fig. 2)* present lower temperature values (appearing "cold" during thermal recovery) [19, 20]. Thermography also allowed complete distinction between BCC and actinic keratosis (AK) lesions, having BCC presented a hypothermic halo, while AK *(Fig. 2)* displayed a hyperthermic one, confirming its precancerous nature [14].

Regarding thermal signature of BCC, authors noticed a synchronous warm up with surrounding skin in the beginning, after which BCC's temperature starts to increase slower than surrounding skin, being clearly recognizable in the end. This behavior was attributed to the fact that BCC is created from the cells responsible for the production of an isolation layer [13].

With current trends continuing towards improvement of the technique and urgent need for noninvasive diagnostic approaches, thermography holds potential to become an available and confident alternative to aid in diagnostic of skin neoplasms and take part in clinical decision-making processes.

In the lab: At IPO-Porto, an experiment was conducted to verify whether the distinction of melanoma and MN was achievable (since both present anatomical resemblances, complicating its distinction). Comparison between the two static thermal profiles showed a clear distinction, which is in accordance with what is already described in literature: the malignant lesion appeared as a hyperthermic curve, differing from the hypothermic curve correlated with the benign tumor. The results proved to be of clinical relevance, with accuracy and sensitivity of 84.2% and 91.3% respectively [7].

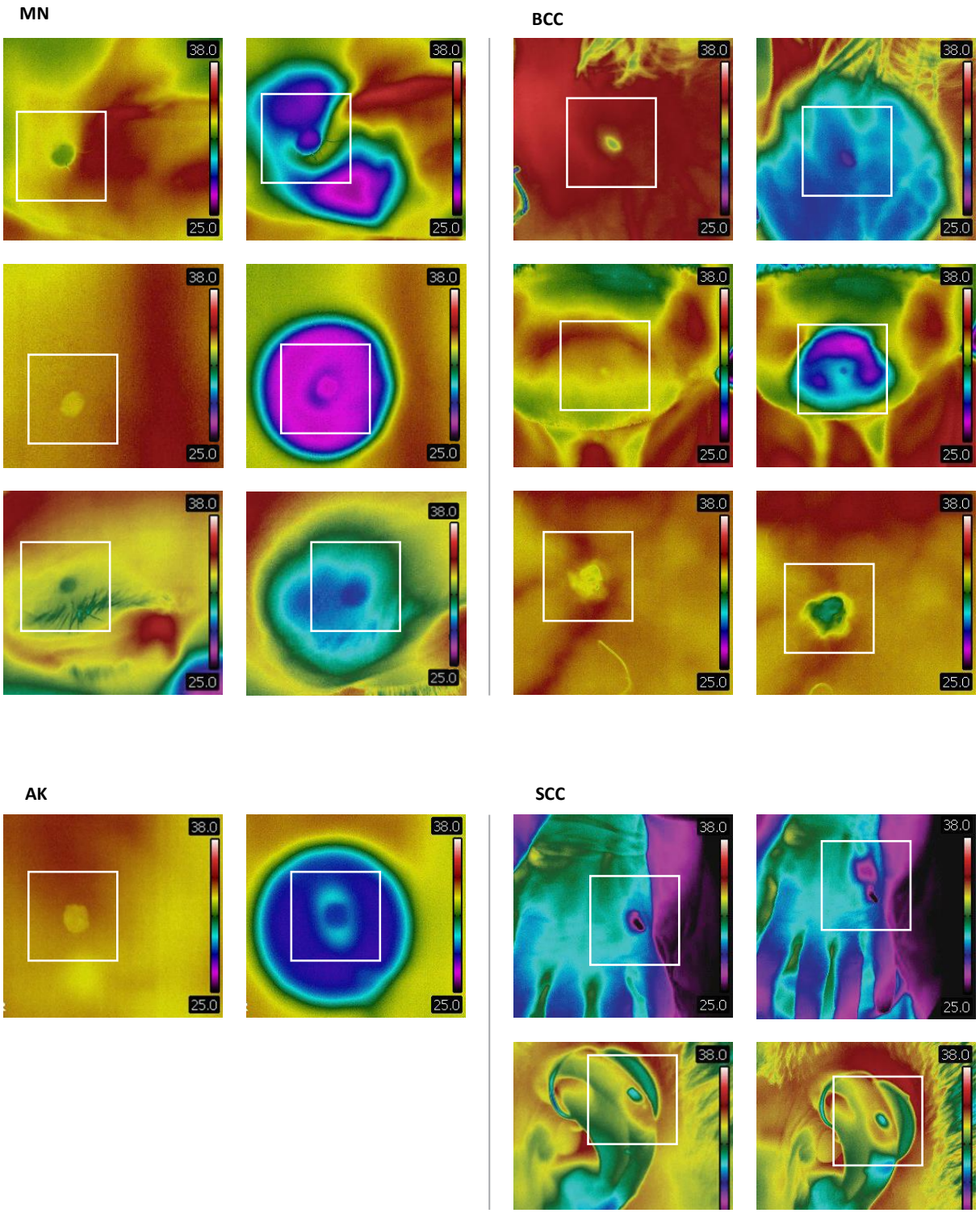

Figure 2 – Static (right) and dynamic (left) thermograms of each mentioned skin lesion. Images kindly provided by Eng. Ana Carolina dos Santos Ribeiro Magalhães

Burn Injuries

Burn injuries are fourth most common type of trauma worldwide, with considerable morbidity and permanent disability, greatly impacting patients' quality of life [21].

To mitigate these consequences, clinicians need to predict healing outcome and guide optimal clinical decision-making.

Burn extent, expressed as total percentage of body surface area, is partly responsible for guidance therapy and determining patient's transference to burn centers. Likewise, location of burns plays a major part, due to higher risk of functional impairment and poor prognosis [22].

In turn, burn depth is a key determinant for burn healing outcome, and also a central element of treatment strategy of burn wounds, in particular on need for surgical grafting [23].

Traditionally, burn wounds are categorized as first, second and third degree, with different healing potential [24].

First degree burns involve the epidermis, healing spontaneously and therefore warrant conservative management [24]. Contrarily, third degree burns affect not only epidermis but all skin layers. There is no chance for spontaneous healing on these burn wounds. As a result, the cornerstone of treatment is early excision and grafting [25]. Second degree burns are found between these two scenarios [1].

Usually, burn wound severity is predicted based on patient's case history together with clinical evaluation of visual and tactile wound characteristics. Although clinical evaluation is frequently used worldwide, its accuracy ranges between 50%-71% [26], being even lower when initial diagnosis is made within first 48 hours, as it requires 3-5 days post burn to determine whether wound shows signs of healing [27].

Due to dynamic character of burn depth, a superficial partial thickness burn may progress into deeper tissues in the first few days following injury, in a process known as burn wound conversion. Over time, burn conversion increases the extent of tissue damage in a way that may not be immediately evident, thus confounding initial assessment [21, 28].

Inherently, visual inspection is imperfect. Hence, a noninvasive, objective, and quantitative approach providing accurate burn wound assessment is needed.

Laser Doppler Imaging (LDI), which assesses wound perfusion, is the most frequently used technique. The accuracy of LDI is as high as 100%, between 2 and 5 days post burn [29]. The

assumption behind its utilization is that remaining microvascular blood flow reflects burn wound's healing potential.

This modality has some serious downsides. First, LDI is costly, restricting its applicability to specialist centers, able to justify the investment. Second, it requires patient to remain still for up to 30 minutes, which is impractical for pediatric population or in situations where patients are experiencing a significant amount of pain. Third, LDI only allows for evaluation of small skin surface areas simultaneously. Finally, it is not accurate during first 1-2 days after injury [28, 30, 31], preventing an early diagnosis.

When transporting thermography for burns' assessment, detected infrared radiation is associated both to cutaneous blood flow in wound's surface and to cell viability [32].

Since deep burns have more blood vessel injury, there will be less tissue perfusion and thus less thermal emission up through skin. Besides, metabolic rate of damaged cells is reduced, which also contributes for decreased heat emission [33]. Therefore, the amount of blood flow disruption correlates with extent of injury in a way that temperature is inversely related to burn depth [21, 31, 34, 35].

The most clinically useful thermographic indicator may actually be minimum temperature from first to second day (despite its lower sensitivity and specificity), as it allows to assess temperature trend of injury: burns that became warmer had a lower scar depth than burns that became cooler [28, 30].

A model to predict treatment modalities needed in each burn wound (re-epithelization, skin graft and amputation) was developed [21]. At last, the agreement rate between the prediction algorithm and treatment modality actually engaged was found to be 90%, proving that prediction ability of thermograms is very accurate and could be used since patient's first evaluation.

Another study exploited thermography's ability to discriminate between burn wounds with different healing periods. The choice of cut off values (high specificity, lower sensitivity) ensured that few wounds would be classified in healing potential categories <14 days and >21 days, but those who were identified in those were almost always correctly classified. This figures obvious implications on treatment decision modalities: it avoids performing unnecessary surgeries and confidently provides conservative treatment to superficial burn wounds [26].

Both studies reiterate a good validity of thermography for judgment of burn wound healing potential and proposed thermographic models that could be used in clinical practice as triage/adjunct tool.

There is no doubt that SIRT has been achieving good significance as a diagnostic tool for burns' assessment. However, there are many factors affecting measured wound temperature, some beyond the control of the investigators, that ultimately are an obstacle for application of SIRT as a stand-alone imaging modality.

A well-established confounding variable is evaporative water loss. Evaporation from wound surface distorts thermographic analysis of burn depth and, as result, both superficial and deep burns appear proportionally cooler (interpreted as falsely deep) [36]. More recently, this difficulty was overcome by using an infrared transparent, non-permeable membrane as wound covering (Clingfilm™), which proved not significantly interfere with thermographic measurements [37].

In present days, DIRT has gained more popularity, because of the additional advantage over static method of eliminating influences of external conditions. In DIRT, not differential temperature but thermal tissue properties (conductivity and diffusivity) are of diagnostic value.

Concerning timing for imaging acquisition, studies point to a relatively early thermographic assessment, ideally in the first three days, which is the most difficult period to assess burn depth clinically [32].

The data presented here favor the use of thermography in several ways. First, its improved sensitivity on measurements of surface temperature produces accurate differential temperatures, which aid for burn depth determination. Second, it may be able to predict the extent of ensuing burn progression in the first days after injury. Third, its notable spatial and temporal resolution allow for visualization of larger skin surface areas in real time [24], which could potentially be used intra-operatively to provide a more precise map of areas requiring debridement as well as to predict dimensions of skin grafts needed [23, 26, 31].

It is a promising technique that could be used for two different purposes: as a triage instrument and as a diagnostic adjunct tool in burn centers. In both situations, cut off values mentioned before could be extremely useful after proper validation [38].

Breast Reconstruction

Breast cancer is one of the most frequent cancer among women, being responsible for the highest number of cancer-related deaths in women [39].

Following mastectomy, the goal of breast reconstruction is to recreate a new breast mound that looks and feels natural, durable and can change with patient over time [40]. Benefits to patient's sexual, physical, and psychological wellbeing are also recognized, rendering it a crucial part of breast cancer treatment [1].

There are several ways to perform breast reconstruction and, although implant-based reconstruction is more widely available, autologous reconstruction is seen as preferable choice in some patients, even though portraying a more complex procedure.

The transference of autologous tissues can be as a pediculated or as a free flap, which requires identification of vascular pedicle for its section and further microsurgical anastomosis on receptor area [1, 39, 41].

Breast reconstruction with free DIEP (deep inferior epigastric perforator) flap has become increasingly popular in autologous breast reconstruction. This flap receives its blood supply from a perforator arising from deep inferior epigastric artery and vein, which, during surgery, will anastomose to internal mammary vessels [42].

This flap is comprised of tissues from patient's lower abdominal wall, providing a substantial quantity of tissue with exceptional texture and skin color and allowing for reconstruction of aesthetically pleasant breasts with little donor site morbidity [1, 41]. The main disadvantage is largely related to its distinct learning curve.

Success of free flap transfer is highly dependent on a robust blood supply and inclusion of a dominant perforator, as it would be the only source of blood supply [40, 43]. Therefore, partial/total flap losses are complications that need to be considered [41].

During preoperative planning, it is vital to map perforators and select the most suitable one [1, 43]. To do so, surgeons need information on hemodynamics properties of a perforator as well as its location *(Fig. 3)* [43-45].

For this purpose, Hand-held Doppler is frequently used to detect perforators' location and their flow characteristics. Besides its inexpensive cost, it obviates the exposure to radiation/contrast agents [40]. It is associated with some major drawbacks: high number of false positive results; identification of very small vessels, unsuitable for perforator flaps and, lastly, aberrance of results comparing to intraoperative observations [40, 43, 46-48]. More importantly, it only

provides a 2D picture of the underlying vascular architecture, a great obstacle when seeking to plan a surgery.

For that reason, Computed Tomography Angiography (CTA) has become the gold standard for perforator mapping. It provides information on the caliber of each perforator, on its intramuscular course and exit point through the anterior rectus fascia, supplying a global 3D map of perforator anatomy [43]. Although CTA can produce valuable information on perforator architecture, it doesn't provide physiological information on flow characteristics [40].

Nevertheless, there is some evidence that warned against sole reliance on CTA perforator mapping as some significant changes had to be pursue intraoperatively [43]. Other obvious disadvantages are its exposure to ionizing radiation and use of intravenous contrast medium [49].

Essentially, a method without these disadvantages would be beneficial and thermography might be an alternative.

When applied to this context, thermography makes use of its active technique and subsequent analysis of rate and pattern of rewarming of hot spots, allowing for a qualitative assessment of all perforators at the same time.

Perforators compete with each other for skin rewarming. Therefore, a rapid rewarming at the hot spot indicates that more blood is being transported to skin surface through a particular perforator compared to others. Additionally, a rapid progression of rewarming at hot spot suggests a better developed vascular network around it [41, 43].

Information on perforator's location is also of great value. From the point of view of dissection, perforators with a perpendicular penetration pattern through the fascia and a short intramuscular course aid to a less complicated dissection procedure [50, 51].

Differently from CTA, DIRT does not provide information on perforator's intramuscular course. Consequently, it is important to employ an adjuvant technique that aids on morphological assessment [43].

Further advantages of CTA over DIRT rests on other situations: first, in situations where a perforator that ends up in subcutaneous tissue might as well be a suitable perforator for DIEP flap but is not otherwise detected by DIRT (it only detects perforators that transport blood to skin's surface); secondly, situations in which patients were already submitted to surgery in whom information on the continuity of the deep inferior epigastric system is of great importance [43].

Intraoperatively, DIRT can be used to confirm perforator's patency, proving that it was not damaged during dissection when a rapid hot spot is seen on the location of perforator's entrance point into the flap. In the negative case, surgeon can elect another suitable perforator.

The most critical part of procedure is anastomosis of donor vessels on thoracic wall recipient vessels [1]. The period immediately after is when arterial thrombosis at vascular anastomosis mainly occurs, being the major cause of flap loss. For that reason, it is postulated that microvascular anastomosis should be assessed for at least 45 minutes before wound closure [41].

Circulation problems during intraoperative period of flap insertion may also occur in the form of external compression/torsion of pedicle and could lead to secondary thrombosis postoperatively. DIRT is able to detect these reperfusion defects by translating it into a rapid disappearance of hot spot pattern on thermogram [52].

Complications related to problems with vascular anastomosis do occur and the most critical period for them seems to be first 24 hours after surgery. Traditionally, surgeons rely on clinical observation using subjective signs. However, thermography could have a place on flap assessment in a more objective way, allowing for differentiating between arterial/venous anastomotic problems (different thermal images attributed to each) [42, 53].

Summarizing, flap's perfusion can be easily monitor with DIRT at any step during or after procedure [41]. Furthermore, it allows the assessment of perfusion/reperfusion in real time and thus provides surgeons with prompt feedback to take corrective actions when necessary. Ultimately, DIRT has the potential to help improving flap design and therefore to reduce the risk of flap failure.

The utility of DIRT has also been described in other flaps such as SIEP and TRAM, not mentioned extensively here.

The same could be applicable for other flaps, namely anterolateral thigh [54], propeller [55], thoracodorsal artery perforator flaps [56] and more.

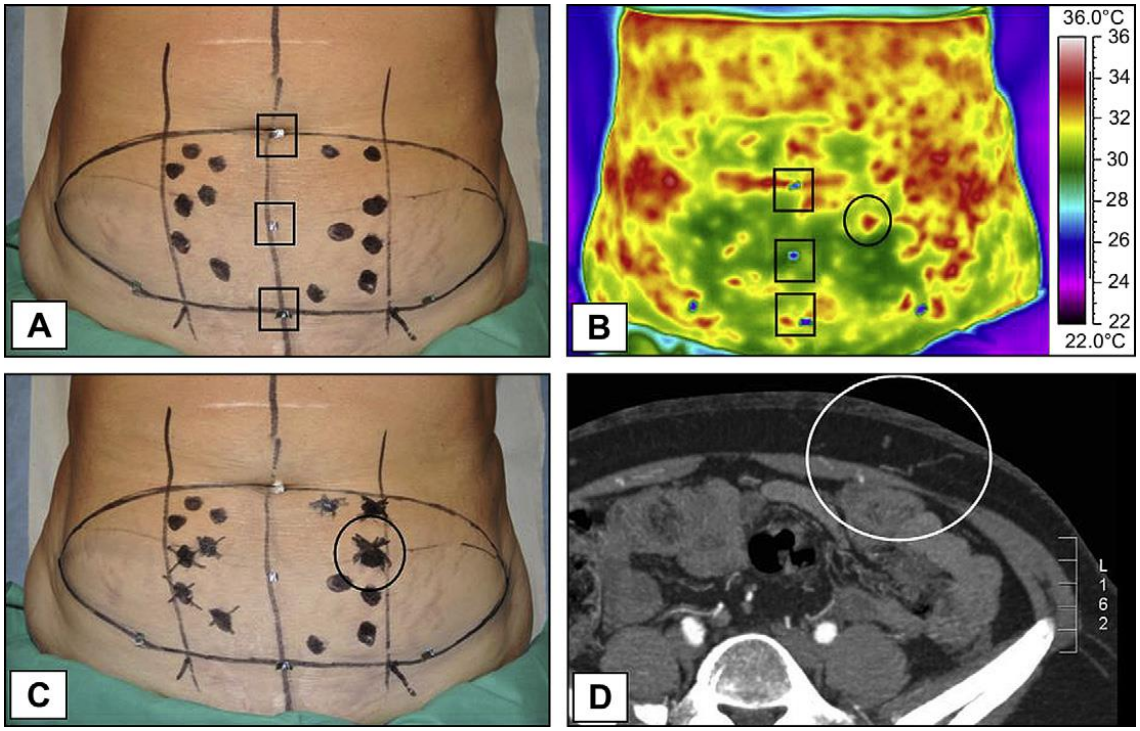

Figure 3 - The flap is outlined on the lower abdomen (A). The black dots represent the locations where arterial Doppler sounds were registered. Small pieces of metal tape were used as reference marks (black squares in A and B). The IR thermogram (B) was taken 3 minutes after 2 minutes of fan cooling. The black circle indicates the first-appearing hot spot. In (C), locations of arterial sounds associated with hot spots are marked with an "X." The selected perforator is marked with a circle and correlates with a suitable perforator on the MDCT scan (white circle in D). Image from "Dynamic infrared thermography", used with author's permission [41]

Other Applications and Future Perspectives

Besides previous mentioned applications, thermography has also been conquering its place on assessing many other pathological conditions. Some of these include evaluation of hemangiomas in pediatric age and planning its further treatment [57]; screening for carpal tunnel syndrome [58]; vascular and pressure ulcers' assessment [59]; diagnosing and screening for surgical site infection in colorectal surgery [60], inflammatory arthritis and soft tissue rheumatism disorders; evaluation of allergic dermatitis and several bullous disorders [61] and lastly, but perhaps, most importantly, detection of breast neoplasms, although not yet able to replace mammography or ultrasound on this ground [62].

Thermography also plays a role in monitoring efficacy of drugs and overseeing thermal responses during photodynamic therapy [14].

The applications of thermography to medical diagnosis and as surgical adjunct are too numerous to list. Nevertheless, this does not mean that present techniques lose importance. Instead, any information should be used cooperatively with existing diagnostic modalities.

In recent years, thermography has gained particular interest as a diagnostic and monitoring modality also in part due to Forward Looking Infrared ONE thermographic camera (FLIR ONE). FLIR ONE is a smartphone-compatible miniature thermal imaging camera that, giving its compact nature, provides accessibility and versatility. Undeniably, it represents a low-cost real-time method, which, for now, was primarily applicated on evaluating skin lesions, detecting/mapping perforators, defining perforasomes and monitoring free flaps [63]. Nevertheless, its spectrum of application could be extended to many more areas [64-67].

Similar to other image acquisition techniques, thermography conveys some non-negligible limitations. Further research focusing on algorithms for analysis, processing and standardization of thermograms is needed in order to define its ranges of specificity and sensitivity [68].

Thermography may be useful in many areas of plastic surgery yet to be explored, aesthetic surgery being an example.

Another area of potential interest could be pathological healing processes, including hypertrophic scars and keloids, which carry a high aesthetical and functional impact [1].

Thermographic evaluation carried out routinely in severely disfigured patients might be a reality in a near future, contributing to better understand its pathophysiology and possibly having therapeutic implications, specifically for local flaps' design [1].

Lastly, thermography could also have potential significance as a telemedicine adjunct and as a triage tool for emergency rooms.

References

1. Valença-Filipe, R., et al., *A utilidade da imagem térmica em cirurgia plástica*, in *Termografia - Imagem Médica e Síndromes Dolorosas*. 2016, Lidel. p. 236-245.
2. Herman, C., *Emerging technologies for the detection of melanoma: achieving better outcomes.* Clinical, cosmetic and investigational dermatology, 2012. **5**: p. 195.
3. Bonmarin, M. and F.-A. Le Gal, *Lock-in thermal imaging for the early-stage detection of cutaneous melanoma: a feasibility study.* Computers in biology and medicine, 2014. **47**: p. 36-43.
4. Baek, Y.S., et al., *Dynamic thermal imaging on actinic keratosis patients: A preliminary study.* Skin Research and Technology, 2019. **25**(2): p. 211-216.
5. Moher, D., et al., *Preferred reporting items for systematic reviews and meta-analyses: the PRISMA statement.* Int J Surg, 2010. **8**(5): p. 336-341.
6. Pirtini Çetingül, M. and C. Herman, *The assessment of melanoma risk using the dynamic infrared imaging technique.* Journal of thermal science and engineering applications, 2011. **3**(3).
7. Magalhaes, C., et al., *Distinguishing melanocytic nevi from melanomas using static and dynamic infrared thermal imaging.* J Eur Acad Dermatol Venereol, 2019. **33**(9): p. 1700-1705.
8. Cheng, T.-Y. and C. Herman, *Analysis of skin cooling for quantitative dynamic infrared imaging of near-surface lesions.* International journal of thermal sciences, 2014. **86**: p. 175-188.
9. Elder, D., *Tumor progression, early diagnosis and prognosis of melanoma.* Acta Oncologica, 1999. **38**(5): p. 535-548.
10. Geller, A.C., et al., *Screening, early detection, and trends for melanoma: current status (2000-2006) and future directions.* Journal of the American Academy of Dermatology, 2007. **57**(4): p. 555-572.
11. Thomas, L., et al., *Semiological value of ABCDE criteria in the diagnosis of cutaneous pigmented tumors.* Dermatology, 1998. **197**(1): p. 11-17.
12. Brasfield, R.D., J.S. Laughlin, and R.S. Sherman, *Thermography in the management of cancer: A preliminary report.* Annals of the New York Academy of Sciences, 1964. **121**(1): p. 235-247.
13. Buzug, T.M., et al. *Functional infrared imaging for skin-cancer screening*. in *2006 International Conference of the IEEE Engineering in Medicine and Biology Society*. 2006. IEEE.
14. Cholewka, A., et al., *Proposal of thermal imaging application in photodynamic therapy—Preliminary report.* Photodiagnosis and photodynamic therapy, 2016. **14**: p. 34-39.

15. Godoy, S.E., et al., *Dynamic infrared imaging for skin cancer screening.* Infrared Physics & Technology, 2015. **70**: p. 147-152.
16. VALIPOORI, G.F., J. Haddadnia, and M. Hashemiyan, *Diagnosis of malignant melanoma based on tissue changes in spatial thermography images.* 2015.
17. Herman, C. and M.P. Cetingul, *Quantitative visualization and detection of skin cancer using dynamic thermal imaging.* JoVE (Journal of Visualized Experiments), 2011(51): p. e2679.
18. Shada, A.L., et al., *Infrared thermography of cutaneous melanoma metastases.* journal of surgical research, 2013. **182**(1): p. e9-e14.
19. Di Carlo, A., et al., *Can video thermography improve differential diagnosis and therapy between basal cell carcinoma and actinic keratosis?* Dermatologic therapy, 2014. **27**(5): p. 290-297.
20. Huriez, C., et al., *Apropos of about 500 cases of dermatoses explored thermographically.* Lille medical: journal de la Faculte de medecine et de pharmacie de l'Universite de Lille, 1977. **22**(8): p. 486.
21. Martínez-Jiménez, M.A., et al., *Development and validation of an algorithm to predict the treatment modality of burn wounds using thermographic scans: Prospective cohort study.* PloS one, 2018. **13**(11).
22. Horta, R., et al., *Thermographic analysis of facially burned patients.* Burns: journal of the International Society for Burn Injuries, 2016. **42**(1): p. 236.
23. Prindeze, N.J., et al., *Examination of the early diagnostic applicability of active dynamic thermography for burn wound depth assessment and concept analysis.* Journal of Burn Care & Research, 2015. **36**(6): p. 626-635.
24. Burmeister, D.M., et al., *Noninvasive techniques for the determination of burn severity in real time.* Journal of Burn Care & Research, 2017. **38**(1): p. e180-e191.
25. Monstrey, S., et al., *Assessment of burn depth and burn wound healing potential.* burns, 2008. **34**(6): p. 761-769.
26. Carrière, M.E., et al., *Validity of thermography for measuring burn wound healing potential.* Wound Repair and Regeneration, 2020. **28**(3): p. 347-354.
27. Simmons, J.D., et al., *Early assessment of burn depth with far infrared time-lapse thermography.* Journal of the American College of Surgeons, 2018. **226**(4): p. 687-693.
28. Burke-Smith, A., J. Collier, and I. Jones, *A comparison of non-invasive imaging modalities: Infrared thermography, spectrophotometric intracutaneous analysis and laser Doppler imaging for the assessment of adult burns.* Burns, 2015. **41**(8): p. 1695-1707.

29. Monstrey, S., et al., *Burn wound healing time assessed by laser Doppler imaging. Part 2: validation of a dedicated colour code for image interpretation.* Burns, 2011. **37**(2): p. 249-256.
30. Miccio, J., et al., *Forward-looking infrared imaging predicts ultimate burn depth in a porcine vertical injury progression model.* Burns, 2016. **42**(2): p. 397-404.
31. Hardwicke, J., et al., *A pilot evaluation study of high resolution digital thermal imaging in the assessment of burn depth.* Burns, 2013. **39**(1): p. 76-81.
32. Liddington, M. and P. Shakespeare, *Timing of the thermographic assessment of burns.* Burns, 1996. **22**(1): p. 26-28.
33. Renkielska, A., et al., *Active dynamic infrared thermal imaging in burn depth evaluation.* Journal of Burn Care & Research, 2014. **35**(5): p. e294-e303.
34. Renkielska, A., et al., *Active dynamic infrared thermal imaging in burn depth evaluation.* J Burn Care Res, 2014. **35**(5): p. e294-303.
35. Renkielska, A., et al., *Burn depths evaluation based on active dynamic IR thermal imaging--a preliminary study.* Burns, 2006. **32**(7): p. 867-75.
36. Hackett, M., *The use of thermography in the assessment of depth of burn and blood supply of flaps, with preliminary reports on its use in Dupuytren's contracture and treatment of varicose ulcers.* British Journal of Plastic Surgery, 1974. **27**(4): p. 311-317.
37. Cole, R., et al., *Thermographic assessment of burns using a nonpermeable membrane as wound covering.* Burns, 1991. **17**(2): p. 117-122.
38. Carrière, M.E., et al., *Validity of thermography for measuring burn wound healing potential.* Wound Repair and Regeneration, 2019.
39. Agyingi, E., T. Wiandt, and S. Maggelakis, *A quantitative model of cutaneous melanoma diagnosis using thermography*, in *Mathematical and Computational Approaches in Advancing Modern Science and Engineering*. 2016, Springer. p. 167-175.
40. Mohan, A.T. and M. Saint-Cyr, *Advances in imaging technologies for planning breast reconstruction.* Gland surgery, 2016. **5**(2): p. 242.
41. de Weerd, L., J.B. Mercer, and S. Weum, *Dynamic infrared thermography.* Clinics in plastic surgery, 2011. **38**(2): p. 277-292.
42. Hennessy, O. and S.M. Potter, *The Use of Infrared Thermography in the Assessment of Free Flap Perforators in Autologous Breast Reconstruction: A Systematic Review.* JPRAS Open, 2019.

43. Weum, S., J.B. Mercer, and L. de Weerd, *Evaluation of dynamic infrared thermography as an alternative to CT angiography for perforator mapping in breast reconstruction: a clinical study.* BMC medical imaging, 2016. **16**(1): p. 43.
44. Busic, V., et al., *The deep inferior epigastric perforator flap for breast reconstruction, the learning curve explored.* Journal of plastic, reconstructive & aesthetic surgery, 2006. **59**(6): p. 580-584.
45. Granzow, J.W., et al., *Breast reconstruction using perforator flaps.* Journal of surgical oncology, 2006. **94**(6): p. 441-454.
46. Giunta, R., A. Geisweid, and A. Feller, *The value of preoperative Doppler sonography for planning free perforator flaps.* Plastic and reconstructive surgery, 2000. **105**(7): p. 2381-2386.
47. Vandevoort, M., J.J. Vranckx, and G. Fabre, *Perforator topography of the deep inferior epigastric perforator flap in 100 cases of breast reconstruction.* Plastic and reconstructive surgery, 2002. **109**(6): p. 1912-1918.
48. Lohman, R.F., et al., *An analysis of current techniques used for intraoperative flap evaluation.* Annals of plastic surgery, 2015. **75**(6): p. 679-685.
49. Thiessen, F.E., et al., *Dynamic infrared thermography (DIRT) in Deep Inferior Epigastric Perforator (DIEP) flap breast reconstruction: standardization of the measurement set-up.* Gland Surgery, 2019. **8**(6): p. 799.
50. Blondeel, P., *One hundred free DIEP flap breast reconstructions: a personal experience.* British journal of plastic surgery, 1999. **52**(2): p. 104-111.
51. Blondeel, P.N., et al., *Perforator flaps: anatomy, technique, & clinical applications*. 2013: CRC Press.
52. de Weerd, L., J.B. Mercer, and L.B. Setså, *Intraoperative dynamic infrared thermography and free-flap surgery.* Annals of plastic surgery, 2006. **57**(3): p. 279-284.
53. Tenorio, X., et al., *Early detection of flap failure using a new thermographic device.* Journal of Surgical Research, 2009. **151**(1): p. 15-21.
54. Xiao, W., et al., *A Prospective Comparative Study of Color Doppler Ultrasound and Infrared Thermography in the Detection of Perforators for Anterolateral Thigh Flaps.* Annals of Plastic Surgery, 2020. **84**(5S): p. S190-S195.
55. Hallock, G.G. *Smartphone thermal imaging can enable the safer use of propeller flaps*. in *Seminars in Plastic Surgery*. 2020. Thieme Medical Publishers.
56. Sjøberg, T., et al., *The Value of Dynamic Infrared Thermography in Pedicled Thoracodorsal Artery Perforator Flap Surgery.* Plastic and Reconstructive Surgery Global Open, 2020. **8**(7).

57. Mohammed, J.A., et al., *Infrared thermography to assess proliferation and involution of infantile hemangiomas: a prospective cohort study.* JAMA dermatology, 2014. **150**(9): p. 964-969.
58. Papež, B.J., et al., *Infrared thermography based on artificial intelligence as a screening method for carpal tunnel syndrome diagnosis.* Journal of International Medical Research, 2009. **37**(3): p. 779-790.
59. Oliveira, A., et al., *Accuracy of ultrasound, thermography and subepidermal moisture in predicting pressure ulcers: a systematic review.* Journal of wound care, 2017. **26**(5): p. 199-215.
60. Siah, C.J.R., et al., *An observational study of temperature and thermal images of surgical wounds for detecting delayed wound healing within four days after surgery.* Journal of clinical nursing, 2019. **28**(11-12): p. 2285-2295.
61. Hamann, D. and H.A. Ricks, *Response to: Thermography: High sensitivity and specificity diagnosing contact dermatitis in patch testing.* Allergology International, 2020. **69**(1): p. 161-162.
62. Milosevic, M., et al., *Early diagnosis and detection of breast cancer.* Technology and Health Care, 2018. **26**(4): p. 729-759.
63. Hallock, G.G., *THE USE OF SMARTPHONE THERMOGRAPHY TO MORE SAFELY UNMASK AND PRESERVE CIRCULATION TO KEYSTONE ADVANCEMENT FLAPS IN THE LOWER EXTREMITY.* Injury, 2020.
64. Xue, E.Y., et al., *Use of FLIR ONE smartphone thermography in burn wound assessment.* Annals of plastic surgery, 2018. **80**(4): p. S236-S238.
65. Nischwitz, S.P., H. Luze, and L.-P. Kamolz, *Thermal imaging via FLIR One-A promising tool in clinical burn care and research.* Burns: journal of the International Society for Burn Injuries, 2020.
66. Ring, E. and K. Ammer, *Infrared thermal imaging in medicine.* Physiological measurement, 2012. **33**(3): p. R33.
67. Hardwicke, J.T., O. Osmani, and J.M. Skillman, *Detection of perforators using smartphone thermal imaging.* Plastic and reconstructive surgery, 2016. **137**(1): p. 39-41.
68. Magalhaes, C., R. Vardasca, and J. Mendes, *Recent use of medical infrared thermography in skin neoplasms.* Skin Research and Technology, 2018. **24**(4): p. 587-591.

Annexes

Publication Guidelines - Acta Médica Portuguesa

Na primeira página/ página de título:

a) Título em **português** e **inglês**, conciso e descritivo

b) Na linha da autoria, liste o Nome de todos os Autores (primeiro e último nome) com os títulos académicos e/ou profissionais e respectiva afiliação (departamento, instituição, cidade, país)

c) Subsídio(s) ou bolsa(s) que contribuíram para a realização do trabalho

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e) Título breve para cabeçalho

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a) Título (sem autores)

b) Resumo em **português** e **inglês**. Nenhuma informação que não conste no manuscrito pode ser mencionada no resumo. Os resumos não podem remeter para o texto, não podendo conter citações nem referencias a figuras.

c) Palavras-chave (*Keywords*). Um máximo de 5 *Keywords* em inglês utilizando a terminologia que consta no Medical Subject Headings (MeSH), http://www.nlm.nih.gov/mesh/MBrowser.html, devem seguir-se ao resumo.

Na terceira página e seguintes:

- Artigos de Revisão

Comprimento máximo: 3500 palavras de texto (não incluindo resumo, legendas e referências). Não pode ter mais do que um total de 4 tabelas e / ou figuras, e não mais de 50-75 referências.

O resumo dos artigos de revisão não deve exceder as 250 palavras e serão estruturados (com cabeçalhos: Introdução, Materiais e Métodos, Resultados, Discussão, Conclusão.

Abreviaturas: Não use abreviaturas ou acrónimos no título nem no resumo, e limite o seu uso no texto. O uso de acrónimos deve ser evitado, assim como o uso excessivo e desnecessário de abreviaturas. Se for imprescindível recorrer a abreviaturas não consagradas, devem ser definidas na primeira utilização, por extenso, logo seguido pela abreviatura entre parenteses. Não coloque pontos finais nas abreviaturas.

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Numere todas as imagens (figuras, gráficos, tabelas, fotografias, ilustrações) pela ordem de citação no texto.
Inclua um título/legenda para cada imagem (uma frase breve, de preferência com não mais do que 10 a 15 palavras).
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Figura: Quando referida no texto é abreviada para Fig., enquanto a palavra Tabela não é abreviada. Nas legendas ambas as palavras são escritas por extenso.
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Legendas: Após as referências bibliográficas, ainda no ficheiro de texto do manuscrito, deverá ser enviada legenda detalhada (sem abreviaturas) para cada imagem. A imagem tem que ser referenciada no texto e indicada a sua localização aproximada com o comentário "Inserir Figura nº 1… aqui".

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Em formato TIF, JPG, BMP, EPS e PDF com 300 *dpis* de resolução, pelo menos 1200 *pixeis* de largura e altura proporcional.
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Se forem citados mais de duas referências em sequência, apenas a primeira e a última devem ser indicadas, sendo separadas por traço.5-9
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- Capítulo de monografia:

Meltzer PS, Kallioniemi A, Trent JM. Chromosome alterations in human solid tumors. In: Vogelstein B, Kinzler KW, editors. The genetic basis of human cancer. New York: McGraw-Hill; 2002. p. 93-113.

Reporting Guidelines – SANRA (narrative review articles)

1) **Justification of the article's importance for the readership**

Page 10: "The importance of this paper lies on the fact that thermography, with its aforementioned advantages, may actually be an image method that can revolutionize some of the areas of Plastic Surgery, where there are currently some gaps in terms of diagnostic and monitoring methods."

2) **Statement of concrete aims or formulation of questions**

Page 10: "The present paper is an attempt to summarize the applications of thermography in some Plastic Surgery fields, as well as the needs and challenges in developing reliable diagnostic and monitoring tools for skin lesions, burn injuries and perforator selection in breast reconstruction surgeries, having thermography a growing interest on each of these grounds."

3) **Description of the literature search**

Page 11: "Literature search on PubMed was conducted in September 2020, as well as a backward citation in order to search for additional relevant citations.
Search strategy was sensitive to texts and abstracts, using the following query: "((thermography) and (plastic surgery)) and ((burns) or (skin lesions) or (flap surgery))".
For eligibility assessment, sequentially screening was made by scanning title and abstract, excluding majority of the studies. Further exclusion was made when remaining full text studies were read."

4) **Referencing**

Page 13: "Melanoma, although accounting for less than 5% of SC, is responsible for most SC deaths (approximately 75%) [6, 7]."

Page 17: "Burn injuries are fourth most common type of trauma worldwide, with considerable morbidity and permanent disability, greatly impacting patients' quality of life [21]."

5) Scientific reasoning

Page 13**: "**According to clinical reports, 5-year survival rate for patients with melanoma is about 99%, if detection occurs in early stages. However, 5-year survival rate drops dramatically to 15% if patient presents an advanced course of disease [8]."

6) Appropriate presentation of data

Page 15: "Comparison between the two static thermal profiles showed a clear distinction, which is in accordance with what is already described in literature: the malignant lesion appeared as a hyperthermic curve, differing from the hypothermic curve correlated with the benign tumor. The results proved to be of clinical relevance, with accuracy and sensitivity of 84.2% and 91.3% respectively [7]."

Page 18: "At last, the agreement rate between the prediction algorithm and treatment modality actually engaged was found to be 90%, proving that prediction ability of thermograms is very accurate and could be used since patient's first evaluation."

Page 13: "Although method's diagnostic accuracy achieves satisfying significance when used by trained practitioners, it only provides qualitative guidelines for melanoma identification. Moreover, it also yields high rates of false positives (specificity: 56%-65%) and frequent false negatives (sensitivity: 47%-89%) [11]."

Sumscore: 12