APPLICATION OF THERMOGRAPHY IN MEDICINE. PART II

Zastosowanie termografii w medycynie. Część II

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Abstract

The first part of the paper presented the physical basis of infrared thermography and thermal imaging cameras (detectors) using the detection of infrared radiation to identify temperature changes in various parts of the human body, which makes infrared thermography useful in complementary diagnosis of diseases in many fields of medicine, such as angiology, internal medicine, aesthetic and reconstructive surgery (as described in the first part of the article), as well as in gynecology and obstetrics, cardiology and heart surgery, oncology, orthopedics, pediatrics, rheumatology, dentistry and urology (as described in this part of the article). Infrared thermography is a promising adjunctive diagnostic method. However, it has both advantages (non-invasiveness, short performance time, ability to generate images of the entire body, simultaneous detection of health problems and subclinical diagnosis), as well as disadvantages (possible impact of external factors, such as changes in ambient temperature, humidity and air movement, on the

Streszczenie

W pierwszej części artykułu przedstawiono podstawy fizyczne termografii oraz kamer termowizyjnych (detektorów), wykorzystujących detekcję promieniowania cieplnego, które umożliwiają wykrycie zmiany temperatur w różnych częściach ciała ludzkiego, dzięki czemu termografia znajduje zastosowanie w diagnostyce uzupełniającej chorób w wielu dziedzinach medycyny: angiologii, chorobach wewnętrznych, chirurgii estetycznej i rekonstrukcyjnej (co opisano w pierwszej części artykułu), a także w ginekologii i położnictwie, kardiologii i kardiochirurgii, onkologii, ortopedii, pediatrii, reumatologii, stomatologii i urologii (co przedstawiono w niniejszej, drugiej części artykułu). Termografia jest obiecującą, uzupełniającą metodą diagnostyczną. Ma zarówno zalety (bezinwazyjność, szybkość wykonania, możliwość obrazowania całego ciała i jednoczesnego wykrycia wielu problemów zdrowotnych oraz diagnozowanie na etapie subklinicznym), jak i wady (wrażliwość pomiaru na czynniki zewnętrzne, takie jak zmiany temperatury otoczenia, wilgotność i ruch powietrza), o których należy pamiętać podczas jej stosowania.

Keywords: oncology; orthopedics; thermography; gynecology and obstetrics; cardiology and cardiac surgery

Słowa kluczowe: onkologia; ortopedia; termografia; ginekologia i położnictwo; kardiologia i kardiochirurgia

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Introduction

The aim of this paper is to present the current knowledge on the applicability of thermography in various medical fields. The first part of this article discussed the physical aspects of infrared thermography (IRT) and thermal imaging cameras (detectors) using infrared (IR) detection, which make it possible to identify temperature changes in different parts of the human body, making IRT applicable for complementary diagnosis of disorders in many medical fields such as angiology, internal medicine, cosmetic and reconstructive surgery (as described in the first part of the paper), as well as gynaecology and obstetrics, cardiology and cardiac surgery, oncology, orthopaedics, paediatrics, rheumatology, dentistry and urology (as presented in this part of the paper)

Thermography in gynaecology and obstetrics

In gynaecology, IRT is used during hysterectomy (performed for oncological reasons) to differentiate anatomical structures (e.g., the ureter and the ostiomeatal complex or the iliac vessels and the ureter), the course and appearance of which may have been altered by the cancerous process or endometriosis [1].

In obstetrics, the method is used to monitor caesarean section wounds for early [2] and late infections, which is particularly important in obese women due to poor wound healing [3]. Additionally, IRT has been used since the 1990s to assess breast temperature during breastfeeding, both in the prevention of mastitis (screening) and to monitor the healing process and treatment efficacy (e.g., the use of ultrasound) [4], as well as in the diagnosis of mastitis in newborns and pubertal girls [5].

Thermography in cardiology and cardiac surgery

In cardiology, intravascular thermography allows for detecting and localising atherosclerotic plaques (unstable ones in particular) in the coronary arteries (the hypothesis of plaque formation is based on the initiation of local, active inflammation, and thus a rise in temperature, which can be detected with a thermal imaging camera) [6].

IRT additionally allows for:
- minimising the risk of thermal oesophageal damage during ablation in atrial fibrillation (rapid detection of critical temperature) [7];
- detecting even a slight decrease in chest wall perfusion after coronary artery bypass grafting (CABG) for ischemic heart disease, and preventing surgical site infection [8];
- diagnosing rare type 1 complex regional pain syndrome (CRPS) after percutaneous coronary intervention (by detecting temperature difference in both forearms) [9].

Thermography in oncology

IRT is a useful tool in oncology for monitoring the risk of radiation dermatitis following radiation therapy for breast cancer in patients after mastectomy and sparing procedures (skin temperature changes are measured at different intervals) [10].

Thermography has been also discussed as a potential tool for detecting and identifying:
- nodular lesions of the breast (both benign and malignant), as an alternative to mammography [11];
- thyroid nodules, including preliminary verification of their malignancy (malignant lesions have a higher temperature than benign ones) [12];
- various types of cancer, malignant and benign skin cancers [13];
- intraocular tumours, including treatment efficacy monitoring in intraocular melanoma by detecting regression (decrease in eye temperature) [14].

Thermography in orthopaedics

IRT is used in orthopaedics:
- for rapid screening diagnosis of bone fractures (hand, foot, collarbone, forearm), in the emergency setting [15];
- as a complementary investigation (in addition to EMG and nerve conduction testing) in the diagnosis of carpal tunnel syndrome (reduced palmar and dorsal temperature in the affected hand) [16];
- in the assessment of patients at risk of Sudeck's syndrome (sympathetic algodystrophy); importantly, across all three phases of the development of this disorder (reduced temperature of the affected limb, delayed temperature rise following cold stimulation) [17];
- for monitoring temperature during orthopaedic surgeries (overheating leads to necrosis and subsequent bone resorption), which allows for modifying the design of surgical instruments and techniques [18];
- for early detection of postoperative complications, such as infections, which are a major problem in hip and knee replacement [19].

Thermography in paediatrics

As a non-invasive and rapid tool, IRT is a valuable diagnostic complement in many areas of paediatrics:
- in paediatric ophthalmology and allergology (increased temperature is observed after intranasal application of nut protein spray in allergic patients) [20], as well as in juvenile arthritis (mainly of the ankle) [21];
- in screening for type I diabetes mellitus (lower skin temperature on IRT after cold stress test in children with diabetes has been noted, although in clinical evaluation, impaired vascular perfusion is not apparent until many years after the disease onset) [22];
- for fracture risk assessment or fracture screening [15];
- for evaluating the healing of burns and wounds (including post-amputation), as well as for deciding on the extent of amputation [23]);
- for monitoring newborns (including preterm infants) at risk for respiratory conditions (based on aberrant temperature changes seen on IRT associated with airflow delay between the chest and abdomen [24]) and necrotizing enterocolitis (based on abdominal temperature differences) [25];
- In paediatric neurology (monitoring of valvular function in children with hydrocephalus, screening for attention deficit hyperactivity disorder) [20].

Thermography in rheumatology

Since joints involved by active inflammation show an increased warmth compared to joints in remission (although the difference is small, and for this reason ultrasound is the most optimal tool [26]), IRT is used in rheumatology to diagnose arthritis (including rheumatoid and juvenile arthritis [21]).

In addition, IRT is used for assessing the Raynaud's phenomenon, as the surface temperature of the hands/fingers is a measure of the overall capillary blood flow [27], which allows to confirm or exclude the diagnosis, and, with additional cold/warm stress, allows to distinguish between primary and secondary conditions, and contributes to the objectivity of patient assessment [28]. This method is also used in the treatment of systemic scleroderma to assess disease activity and response to treatment [27].

Thermography in dentistry

IRT is used in dentistry:

- for the diagnosis of periapical inflammatory lesions, acute pulpitis with apical periodontitis, as well as acute and chronic periapical abscess (all in the preclinical phase, which allows rapid diagnosis and treatment) [29];
- in implantology (elevated bone temperature when drilling for an implant is a negative prognostic factor as it disrupts the physiological balance of proteins in bone cells [30]);
- in dental surgery (for temperature monitoring during the application of different types of techniques during osteotomy: contact and non-contact Er:YAG laser treatment, piezoelectric surgery and surgical drill, to assess for potential tissue overheating, which is a negative prognostic factor [31]);
- endodontics (for assessing root temperature when using different filling techniques, assessing the volume of endodontic filling materials and potential empty spaces, which are a negative prognostic factor [32]);
- in oral inflammation (e.g., caused by wearing dentures, also as a screening and prognostic test [33]).

Thermography in urology

IRT is used in urology to monitor genitourinary inflammation, prostatitis, testicular inflammation, bladder and urinary tract inflammation [34], as well as to diagnose altered seminal vasculature in young men [35]. IRT is also used to assess renal blood flow, which is particularly useful in patients with diabetes mellitus or heart disease, and during transplantation procedures [36].

Conclusions

Thermal imaging is a promising complementary diagnostic approach used in many fields of medicine. Like any other diagnostic or therapeutic tool, IRT has both advantages and disadvantages. Advantages include non-invasiveness, short duration, the possibility of full-body imaging and simultaneously detecting multiple health problems, and, particularly importantly, the possibility to diagnose a given disorder at its subclinical stage, allowing for rapid implementation of effective treatment. Disadvantages that should be considered when using this method include the possible impact of external factors on the measurement (such as changes in ambient temperature, humidity and air movement), poor resolution, especially in the case of cheaper, low-class systems, which makes interpretation of the result difficult, as well as the high price of high-end devices.

References

1. Angioli R, Terranova C, Plotti F, et al. Real-time infrared thermography for ureter detection during hysterectomy. J Surg Res, 2012; 178: 539–544. doi: 10.1016/j.jss.2012.07.006
2. Childs C, Siraj MR, Fair FJ, et al. Thermal territories of the abdomen after caesarean section birth: infrared thermography and analysis. J Wound Care, 2016; 25: 499–512. doi: 10.12968/jowc.2016.25.9.499
3. Childs C, Siraj MR, Fair FJ, et al. Thermal territories of the abdomen after caesarean section birth: infrared thermography and analysis. J Wound Care, 2016; 25: 499–512. doi: 10.12968/jowc.2016.25.9.499
4. Potter H, Horne R, Le May K, et al. The sensitivity of thermography to temperature changes in breast tissue. Aust J Physiother, 1997; 43: 205–210. doi: 10.1016/s0004-9514(14)60411-6
5. Stricker T, Navratil F, Sennhauser FH. Mastitis in early infancy. Acta Paediatr, 2005; 94: 166–169. doi: 10.1111/j.1651-2227.2005.tb01885.x
6. Sharif F, Murphy RT. Current status of vulnerable plaque detection. Catheter Cardiovasc Interv, 2010; 75: 135–144. doi: 10.1002/ccd.22164
7. Crozier I, Daly M, Lim G, et al. Esophageal infrared thermography during atrial fibrillation ablation. Heart Rhythm, 2015; 12: 2362–2363. doi: 10.1016/j.hrthm.2015.07.037
8. Rasche S, Kleiner C, Müller J, et al. Infrared thermographic imaging of chest wall perfusion in patients undergoing coronary artery bypass grafting. Ann Biomed Eng, 2022; 50: 1837–1845. doi: 10.1007/s10439-022-02998-x
9. Pérez-Concha T, Tijero B, Acera M, et al. Usefulness of thermography in the diagnosis and classification of complex regional pain syndrome. Neurologia (Engl Ed), 2020; 38: 342–349. doi: 10.1016/j.nrl.2020.10.011
10. Plaza D, Baic A, Lange B, et al. Comparison of the thermal reaction of patients after conserving procedures and after mastectomy to the radiation dose obtained during radiotherapy. Int J Environ Res Public Health, 2022; 19: 16085. doi: 10.3390/ijerph192316085
11. Kolarić D, Herceg Z, Nola IA, et al. Thermography-a feasible method for screening breast cancer? Coll Antropol, 2013; 37: 583–588
12. Damião CP, Montero JRG, Moran MBH, et al. Application of thermography in the diagnostic investigation of thyroid nodules. Endocr J, 2021; 68: 573–581. doi: 10.1507/endocrj.EJ20-0541
13. Verstockt J, Verspeek S, Thiessen F, et al. Skin cancer detection using infrared thermography: measurement setup, procedure and equipment. Sensors (Basel), 2022; 22: 3327. doi: 10.3390/s22093327
14. Modrzejewska A, Cieszyński Ł, Zaborski D, et al. Thermography in clinical ophthalmic oncology. Arq Bras Oftalmol, 2021; 84: 22–30. doi: 10.5935/0004-2749.20210004
15. der Strasse WA, Campos DP, Mendonça CJA, et al. Detecting bone lesions in the emergency room with medical infrared thermography. Biomed Eng Online, 2022; 21: 35. doi: 10.1186/s12938-022-01005-7

16. Bargiel P, Czapla N, Prowans P, et al. Thermography in the diagnosis of carpal tunnel syndrome. Open Med (Wars), 2021; 16: 175–182. doi: 10.1515/med-2021-0007
17. Bruehl S, Lubenow TR, Nath H, et al. Validation of thermography in the diagnosis of reflex sympathetic dystrophy. Clin J Pain, 1996; 12: 316–325. doi: 10.1097/00002508-199612000-00011
18. Shu L, Bai W, Shimada T, et al. Thermographic assessment of heat-induced cellular damage during orthopedic surgery. Med Eng Phys, 2020; 83: 100–105. doi: 10.1016/j.medengphy.2020.05.014
19. Scheidt S, Rüwald J, Schildberg FA, et al. Systematic review on the value of infrared thermography in the early detection of periprosthetic joint infections. Z Orthop Unfall, 2020; 158: 397–405. doi: 10.1055/a-0969-8675
20. Owen R, Ramlakhan S. Infrared thermography in paediatrics: a narrative review of clinical use. BMJ Paediatr Open, 2017; 1: e000080. doi: 10.1136/bmjpo-2017-000080
21. Lasanen R, Piippo-Savolainen E, Remes-Pakarinen T, et al. Thermal imaging in screening of joint inflammation and rheumatoid arthritis in children. Physiol Meas, 2015; 36: 273–282. doi: 10.1088/0967-3334/36/2/273
22. Zotter H, Kerbl R, Gallistl S, et al. Rewarming index of the lower leg assessed by infrared thermography in adolescents with type 1 diabetes mellitus. J Pediatr Endocrinol Metab, 2003; 16: 1257–1262. doi: 10.1515/jpem.2003.16.9.1257
23. Saxena AK, Willital GH. Infrared thermography: experience from a decade of pediatric imaging. Eur J Pediatr, 2008; 167: 757–764. doi: 10.1007/s00431-007-0583-z
24. Goldman LJ. Nasal airflow and thoracoabdominal motion in children using infrared thermographic video processing. Pediatr Pulmonol, 2012; 47: 476–486. doi: 10.1002/ppul.21570
25. Rice HE, Hollingsworth CL, Bradsher E, et al. Infrared thermal imaging (thermography) of the abdomen in extremely low birthweight infants. J Surg Radiol, 2013; 1. doi: 10.1515/jpm-2012-0239
26. Tan YK, Hong C, Li H, et al. Thumboo J. Thermography in rheumatoid arthritis: a comparison with ultrasonography and clinical joint assessment. Clin Radiol, 2020; 75: 963.e17–963.e22. doi: 10.1016/j.crad.2020.08.017
27. Chojnowski M. Infrared thermal imaging in connective tissue diseases. Reumatologia, 2017; 55: 38–43. doi: 10.5114/reum.2017.66686
28. Pauling JD, Shipley JA, Harris ND, et al. Use of infrared thermography as an endpoint in therapeutic trials of Raynaud's phenomenon and systemic sclerosis. Clin Exp Rheumatol, 2012; 30: S103–S115
29. Aboushady MA, Talaat W, Hamdoon Z, et al. Thermography as a non-ionizing quantitative tool for diagnosing periapical inflammatory lesions. BMC Oral Health, 2021; 21: 260. doi: 10.1186/s12903-021-01618-9
30. Möhlhenrich SC, Modabber A, Steiner T, et al. Heat generation and drill wear during dental implant site preparation: systematic review. Br J Oral Maxillofac Surg, 2015; 53: 679–689. doi: 10.1016/j.bjoms.2015.05.004
31. Gabrić D, Aumiler D, Vuletić M, et al. Thermal evaluation by infrared thermography measurement of osteotomies performed with Er:YAG laser, piezosurgery and surgical drill-an animal study. Materials (Basel), 2021; 14: 3051. doi: 10.3390/ma14113051
32. Suassuna FCM, de Araújo DKM, Amorim AMAM, et al. Thermal and volumetric assessment of endodontic filling techniques using infrared thermography and micro-CT. J Oral Sci, 2023; 65: 34–39. doi: 10.2334/josnusd.22-0285
33. Iosif L, Preoteasa CT, Murariu-Măgureanu C, et al. Clinical study on thermography, as modern investigation method for Candida-associated denture stomatitis. Rom J Morphol Embryol, 2016; 57: 191–195
34. Kesztyüs D, Brucher S, Kesztyüs T. Use of infrared thermography in medical diagnostics: a scoping review protocol. BMJ Open, 2022; 12: e059833. doi: 10.1136/bmjopen-2021-059833
35. Belay RE, Huang GO, Shen JK, et al. Diagnosis of clinical and subclinical varicocele: how has it evolved? Asian J Androl, 2016; 18: 182–185. doi: 10.4103/1008-682X.169991
36. Pabisiak K, Romanowski M, Myślak M, et al. Variations in temperature of the donor kidney during cold ischemia time and subsequent assessment of reperfusion using the application of thermovision camera. Transplant Proc, 2003; 35: 2157–2159. doi: 10.1016/s0041-1345(03)00777-2