Imaging and Radiation Research (2021) Volume 4 Issue 1
doi:10.24294/irr.v4i1.1740

REVIEW ARTICLE

Application of infrared thermography in radiation protection and other medical fields

Zhen Yao, Minyan Zhao, Yulong Liu*

Second Affiliated Hospital of Soochow University, Suzhou 215004, Jiangsu, China. E-mail: yulongliu2002@126.com

ABSTRACT

Infrared thermal imaging technology is another new branch for medical imaging after traditional medical imaging technologies such as X-ray, ultrasound and magnetic resonance (MRI). It has the advantages of noninvasive, nondestructive, simple and fast. Its application can radiate multiple clinical departments. This paper mainly expounds the principle, influencing factors of medical infrared thermography and its application in radiation protection and other medical fields.

Keywords: Infrared Thermography; Radiation Protection; Principle; Influencing Factors; Clinical Application

ARTICLE INFO

Received: 26 October 2021
Accepted: 14 December 2021
Available online: 29 December 2021

1. Introduction

As early as 480 BC, it was described in the works of Hippocrates that the heat energy emitted by the human body can be used to diagnose diseases. If a layer of soil is coated on the surface of the patient's body, it is inferred that there may be lesions at the dry crack of the soil[1]. In 1800, british astronomer William Hirschel discovered the relationship between heat and infrared radiation[2]. The application of infrared thermography in clinical medicine mainly began in the late 1950s for the diagnosis of breast tumors. In 1956, R. Lawson used infrared technology to confirm that the body surface temperature of breast cancer was higher than that of normal parts[3], which opened the door to the research of medical infrared thermal imaging technology. At present, the International Atomic Energy Agency (IAEA) has incorporated infrared thermal imaging technology into the radiation damage protection guidelines. In addition, infrared thermal imaging technology has also been widely used in early diagnosis and treatment of tumors, prognosis evaluation of cardiovascular diseases, prognosis of inflammatory diseases, acupuncture and moxibustion in traditional Chinese medicine, etc.

2. Principle of medical infrared thermography

All objects with a temperature higher than absolute zero in nature will emit infrared radiation(infrared). Medical infrared can be divided into far infrared and near infrared. The wavelength of far infrared is 1.5 ~ 400 μm. The depth of penetrating human tissue is 2 mm, and most of them are absorbed or reflected by the surface skin. Near infrared wavelength is 0.76 ~ 1.5 μm. The penetrable depth is 5 ~ 10 mm[4]. The human body also produces infrared radiation, and the wavelength of electromagnetic wave is mainly in the far-infrared region, with a wavelength range of 4 ~ 14 μm and its peak about 9.34 μm[5]. Medical infrared thermal imaging technology is the product of the combination of medical technology, infrared camera technology and computer multimedia technology. It collects the far-infrared radiant heat generated by the human body and forms an intuitive temperature color map through computer processing.

If the human body function changed, the temperature of the lesion location would change significantly compared with the normal tissue. This change can be captured by infrared thermal imaging technology, so as to help diagnose the disease and judge the location and scope of the lesion[6].

3. Influencing factors of infrared thermal imaging

3.1 Temperature

Too high or too low of ambient temperature will affect the far-infrared measurement, resulting in the decline of the infrared image definition and quality of the measured object, and the appearance of flocculent edges in the image. When the measured object is an organism, if the temperature difference between the organism and the environment was too large, the organism would experience heat conduction with the environment, thus affecting the measurement results. In addition, during far-infrared measurement, the ambient temperature should be controlled below the temperature of the measured object to reduce thermal noise and prevent the accuracy and accuracy of the image from being affected. During actual operation, the far-infrared thermal imaging technology should be started up 30 minutes before the test, the camera should be fixed at a position 1.5 ~ 2.5 m away from the subject, the room temperature should be controlled at about 20 ~ 24 ℃[7], and the humidity should be maintained at 50% ~ 60%.

3.2 Wind speed

When the infrared equipment is in operation, the air flow in the measurement environment will affect the measurement results. Because the acceleration of air flow will enhance the convective heat transfer between the surface of the measured object and the environment, and reduce the temperature difference between the measured object and the surrounding environment. When the measured object is an organism, the high-speed flowing air will increase the evaporation of the organism's sweat, resulting in the decrease of the organism's temperature. Therefore, when the inf rared equipment is working, the air flow in the environment should be controlled to avoid affecting the precision and accuracy of the infrared image. During the actual operation, the indoor air conditioner should avoid blowing the subject's body directly so as to reduce the impact of air flow rate on the experimental results.

3.3 Light

Light has an impact on far-infrared measurement. During the measurement process, a suitable measurement environment should be selected to prevent the change of light from affecting the measurement results, so as to enhance the accuracy and comparability of infrared imaging. During the actual operation, the indoor light should be kept soft and comfortable, and the strong light should be avoided directly on the subject's body[8] The subject shall enter the laboratory 15 ~ 20 min in advance to adapt to the laboratory environmental conditions. Sunbathing is prohibited one week before the experiment[9].

3.4 Color

The influence of color on infrared thermal imaging measurement results can be ignored.

4. Application of infrared thermal imaging in radiation protection

4.1 Theoretical basis

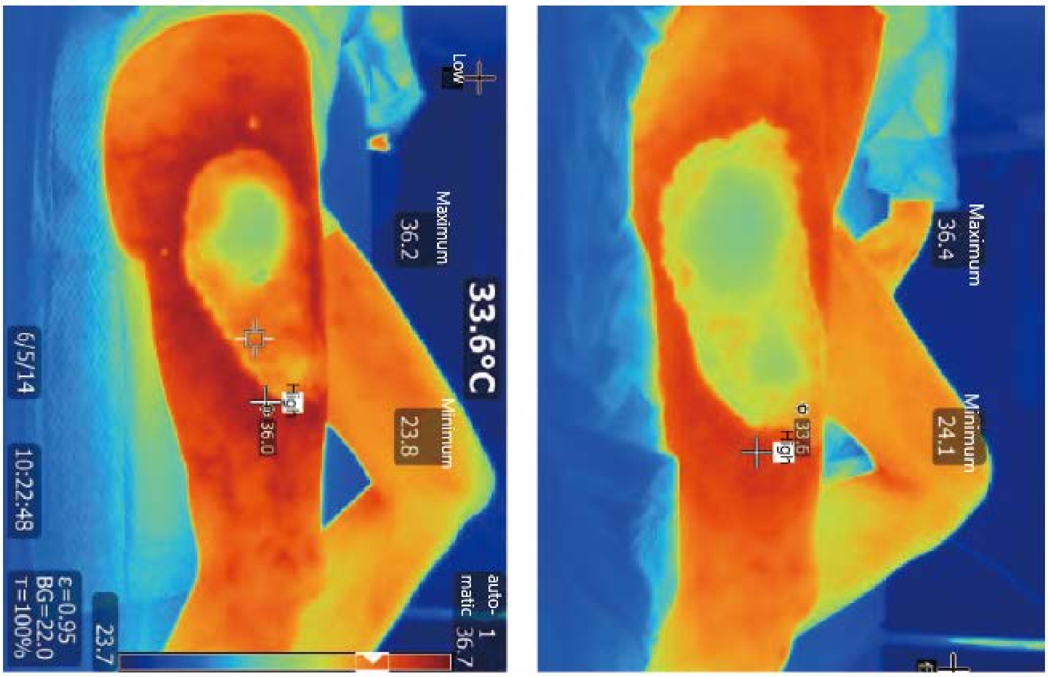
In the process of radiation protection, diagnosis and treatment of radiation injury, physical dosimetry is very important. There is no appropriate biological dosimetry method in the early stage of local radiation injury, so the detailed history of the accident should be recorded. In terms of physical examination, color photo data should be used, and daily skin reactions should be observed. In the case of local radiation damage, the electron spin resonance method can be used to estimate the dose of teeth, clothes, buttons, earrings or any organic substance. In the first week after the accident, the daily blood cell count can help to predict the possibility of systemic exposure, because only some nonspecific changes, such as mild leukocytosis or rapid erythrocyte sedimentation rate, can be observed in local radiation injury. After local exposure to the dose range of 5 ~ 10 Gy, chromosomal aberrations can only be found in a small number of cultured lymphocytes, which provides qualitative rather than quantitative information[10].

At present, two diagnostic methods can be used to assess the severity of local overexposure: Thermal isotope method and radioisotope method. When the irradiated area is compared with the corresponding non irradiated area, both are the most reliable. Thermal imaging can be used to identify any injury and determine its degree. It is an effective and sensitive local radiation injury detection technology, especially in the early and incubation period when the clinical symptoms are not obvious. In addition, both the contact thermal imager and the infrared remote thermal imager can be used for evaluation. Although the latter technique may have more advantages in the diagnosis of whole-body local irradiation, it is limited to the affected limbs, and the cost is much higher. When ^{99m}Tctitanate is injected intravenously, radioisotope method can be used to record vascular circulation of organs or body parts, and its distribution can be monitored by scintillation camera. Thermography and radioisotope methods are complementary. They can not perform accurate dose assessment, but can help to assess the severity of clinical injury[10].

In addition, many new technologies, such as hair cortex cell count, are being studied as indicators of partial human radiation exposure[10].

4.2 Application cases: Clinical treatment of patients with “5.7” ^{192}Ir source radiation accident in Nanjing

In 2014, the Liu Yulong team of the Second Affiliated Hospital of Suzhou University applied the Ti 400 infrared thermal imager produced by fluke company of the United States to perform infrared thermal imaging examination on the radiation injury area and required parts of the right lower limb at different times during the clinical treatment of patients with “5.7” ^{192}Ir source radiation accident in Nanjing.



a 30 days after exposure　　b 60 days after exposure

Figure 1. Results of infrared thermal imaging at different time after exposure.

At different stages after irradiation, the patients were detected by infrared thermal imager on the radiation injury area and corresponding parts of the right lower limb. The results showed that on the 13th day, after irradiation, the temperature of the right thigh was 35.5 ~ 36.8 ℃, which was 2 ~ 3 ℃ higher than that of the left; 30 days after exposure, the temperature in this area was 1 ~ 2 ℃ higher than that on the left (**Figure 1a**); 60 days after exposure, the temperature in this area was less than 1 ℃ higher than that on the left side (**Figure 1b**). Generally speaking, the skin becomes degenerated and necrotic when the temperature rises.

In the course of treatment, the patient's radiation injury wound of the right lower limb continued to progress. After the initial zonal dressing change scheme—"sandwich" dressing change and debridement, the scope of wound ulcer necrosis gradually expanded. The infrared thermal imaging irradiation showed that the skin temperature around the wound was about 1.5 ℃ higher than that of normal skin. After the boundary of the injured wound was clear, the myocutaneous flap was transplanted for many times and the umbilical cord MSCs were infused. After the above treatment, the radiation injury wound of the patient's right lower limb and the wound in the back skin removal area were completely healed[11].

5. Application of infrared thermography in medical field

Table 1 lists the main applications of red spot thermal imaging technology in the medical field.

Table 1. Application of infrared thermal imaging technology in medical field

Disease	Application
Tumour	Breast cancer: Infrared thermal imaging technology was first applied to the early detection of breast cancer. Since 1957, through the research of Lawson[12], Williams[13], Ng[14], Hossein *et al*., the results show that infrared thermal imaging technology can successfully evaluate breast cancer.
	Skin cancer: Infrared thermography is also used to detect skin cancer. Godoy *et al*.[7] used dynamic infrared thermography to detect skin cancer.
	Schwannoma: The Third Affiliated Hospital of Guangzhou Medical University found the sacral schwannoma by infrared thermography and successfully treated a patient with a history of leg pain for more than 10 years[15].
	Thyroid cancer: At the end of the 20th century, Wang *et al.* used infrared thermography to detect 103 patients with pathological confirmation in the affected side. The diagnostic coincidence rate of thyroid cancer was 88.9% (32/36). The diagnostic coincidence rate of benign lesions was 83.6% (56/67)[16].
	Nasopharyngeal carcinoma: In 2000, Pang *et al.*[17] used infrared thermal imaging technology to compare the nasopharyngeal thermogram of healthy people and 184 patients with nasopharyngeal carcinoma and concluded that patients with cervical lymph node enlargement, such as those with increased IFI temperature, and changes in nose shape and temperature difference, can be basically diagnosed in combination with clinical practice.
	Others: Clinical research shows that infrared thermography detection has important clinical value in the early detection and diagnosis of oral cancer[18], laryngeal tumor, neck mass[19].
Cardio cerebral vessels	In recent years, infrared thermal imaging technology has been more and more widely used in cardiovascular diseases, mainly in quantitative vasospasm response in Reynolds phenomenon[20–23], deep vein thrombosis[24], diabetes foot[25], ICD (ischemic cerebrovascular disease), cerebral insufficiency, cerebral hemorrhage, myocardial insufficiency[26], early monitoring of hypertension[27], evaluation after vascular surgery[28], and other fields.
Inflammatory disease	Infrared thermography can reflect the outcome of inflammatory diseases in human body. It has been used to analyze and observe the treatment of arthritis, rheumatism, pelvic inflammation, appendicitis, mastitis, ankylosing spondylitis, lower extremity phlebitis, epididymitis, pneumonia and other diseases[29–31].
Other	Infrared thermography should also be used for body temperature monitoring after hormone use[32], monitoring of infection indicators after knee surgery[33], monitoring of recovery process after decompression surgery for carpal tunnel syndrome[34], recording temperature changes after pain and reflecting the nature, scope and degree of pain[35]. As one of the visualization and objectification technical means of traditional Chinese medicine research, infrared thermal imaging technology is an important part of the development of modern traditional Chinese medicine[36]. In 2018, Yi *et al.* applied it to the "prevention of disease" project of traditional Chinese medicine[37], and it is also applied to many traditional Chinese medicine fields, such as acupuncture[38], research on the thermal structure of phlegm dampness constitution[39].

6. Conclusion

Since its application in the medical field in 1957, infrared thermal imaging technology has experienced a rapid development stage, especially in the protection and diagnosis of radiation injury, early diagnosis of tumors, prognosis evaluation of cardiovascular diseases, analysis and treatment observation of inflammatory diseases. In recent years, infrared thermal imaging technology has also been widely used in the field of traditional Chinese medicine. It is highly consistent with the core concepts of the holistic view and syndrome differentiation view of traditional Chinese medicine, and can provide ideas for the modernization of traditional Chinese medicine diagnosis. However, the research on infrared thermal imaging technology in traditional Chinese medicine has not yet formed a system, which affects its popularization, so it is worth further research. Although the image acquisition of the infrared thermal imaging system is still affected by temperature, humidity, air flow rate and other factors, the standardized measurement environment is gradually improved. We believe that the infrared thermal imaging technology will make a great contribution to the development of radiation protection and Chinese and Western medicine.

Conflict of interest

The authors declared no conflict of interest.

References

1. Ring F, Jung A, Zuber J. New opportunities for infrared thermography in medicine. Acta Bio-Optika et Informatica Medica 2009; 15(1): 28–30.
2. Lv S, Wang Y, Li H, *et al*. The significance and principle of infrared thermal radiation of the human body. Chinese Journal of Current Praticle Medicine 2004; 3(1): 33–34.
3. Ammer K. Temperature gradients in Raynaud's phenomenon. Comparison by gender, age class and finger involvement. Thermology International 2010; 20(3): 100–109.
4. Wen J, Zheng C, Li S. The application of infrared radiation in medicine. Foreign Medical Sciences Section of Radiation Medicine and Nuclear Medicine 2004; 28(5): 237–240.
5. Wei Z, Tong M. Yiyong hongwai rexiang zhenduan zhong de shengwu he wuli jili (Chinese) [The biological and physical mechanism of infrared thermal imaging in medical diagnosis]. Life Science Instruments 2005; 3(2): 20–22.
6. Zhang R, Zhu S, Qu Q, *et al*. Research progress of infrared thermal imaging technology in western medical filed. China Health Industry 2019; 16(04): 197–198.
7. Godoy SE, Hayat MM, Ramirez DA, *et al*. Detection theory for accurate and non-invasive skin cancer diagnosis using dynamic thermal imaging. Biomedical Optics Express 2017; 8(4): 2301–2323.
8. Yuan Y. Medical digital infrared thermal imaging technology introduction. Zhengzhou: Zhengzhou University Press; 2013.
9. Namkoong S, Shim JM, Kim SJ, *et al*. Effects of different sitting positions on skin temperature of the lower extremity. Journal of Physical Therapy Science 2015; 27(8): 2637–2640.
10. International Atomic Energy Agency (IAEA). Diagnosis and treatment of radiation injuries. Vienna: IAEA; 1998.
11. Liu Y, Wang Y, Yu D, *et al*. Medical management of the victim exposed to ^{192}Ir source at "5.7" accident in Nanjing. Chinese Journal of Radiological Medicine and Protection 2016; 36(5): 324–330.
12. Lawson R. Implications of surface temperatures in the diagnosis of breast cancer. Canadian Medical Association Journal 1956; 75(4): 309–310.
13. Williams KI, Williams FJ, Handley RS. Infra-red thernometry in the diagnosis of breast cancer. The International Journal of Cancer 1961; 2(7217): 1378–1381.
14. Ng EYK. A review of thermography as promising non-invasive detection modality for breast tumor. International Journal of Thermal Sciences 2009; 48(5): 849–859.
15. Xiao Y, Lu Z, SiTu J. Hongwai rechengxiangtu faxian dishenjing qiaoliu 1 li (Chinese) [A case of sacral schwannoma was found by infrared thermal imaging]. Chinese Journal of Pain Medicine 2018; 24(9): 718–720.
16. Wand P, Zhang Q, Ruan J, *et al*. Hongwai rexiangtu zhenduan jiazhuangxianai de tantao (Chinese) [Discussion on the diagnosis of thyroid cancer by infrared thermography]. Chinese Journal of Medical Imaging Technology 1997; (6): 510–511.
17. Lu G, Pang W, Wang L. The application of diagnosis in the Nessopharyngel Cancer (NPC) by infrared imaging system. Laser & Infrared 2001; 31(1): 42–44.
18. Liu J, Yang M, Sun C. Weibo jiare timo, hongwairechengxiang cewen guancha—Fu 9 li kouqiangai weibo reliao linchaung (Chinese) [Microwave heated bulk mode, infrared thermal phase temperature observation—Microwave hyperthermia of 9 cases of oral cancer was reported]. Stomatology 1992; (2): 78–80.
19. Huang X, Yang C, Wu X, *et al*. Hongwai rexiangshu yongyu houbu zhongliu ji jingbu zhongkuai zhenduan de tantao (Chinese) [The application of external thermal imaging in the diagnosis of laryngeal tumors and neck tumors]. Journal of Clinical Otorhinolaryngology. Head and Neck Surgery 1990; (1): 1–3.
20. Darton K, Black CM. Pyroelectric vidicon thermographyand cold challenge quantify the severity ofraynaud's phenomenon. Rheumatology 1991; 30(3): 190–195.
21. Caramaschi P, Codella O, Poli G, *et al*. Use of

computerized digital thermometry for diagnosis ofraynaud's phenomenon. Angiology 1989; 40(10): 863–871.

22. Ammer K. Diagnosis of Raynaud's phenomenon by thermography. Skin Research and Technology 1996; 2(4): 182–185.
23. Cherkas LF, Carter L, Spector TD, *et al*. Use of thermographic criteria to identify Raynaud's phenomenon in a population setting. The Journal of Rheumatology 2003; 30(4): 720–722.
24. Aronen HJ, Suoranta HT, Taavitsainen MJ. Thermography in deep venous thrombosis of the leg. American Journal of Roentgenology 1981; 137(6): 1179–1182.
25. Armstrong DG, Lipsky BA, Polis AB, *et al*. Does dermal thermometrypredict clinical outcome in diabetic foot infection? Analysis of data from the SIDESTEP* trial. International Wound Journal 2006; 3(4): 302–307.
26. Yao W, Xue Y, Luo Y, *et al*. Using infrared thermography to diagnose ischemic cerebrovascular disease and evaluate its treatment effect. Chinese Journal of Laser Medicine & Surgery 2007; 16(2): 99–103.
27. Liu W, Sun G, Jia W, *et al*. Analysis of the characteristics of infrared imaging in pre-hypertension patients. Journal of Hunan University of Chinese Medicine 2016; 36(9): 86–89.
28. Li Q, Li K, Fan H, *et al*. Infrared thermo-imaging inspection in coronary artery disease. Chinese Journal of Medical Imaging Technology 2008; (S1): 205–207.
29. Su P, Huang D, Xiong C. The diagnostic value of infrared thermography in pelvic inflammatory disease. Chinese Journal of Physical Medicine and Rehabilitation 2004; 26(3): 183–185.
30. Ring EFJ, Ammer K. Infrared thermal imaging in medicine. Physiological Measurment 2012; 33(3): 33–46.
31. Cheng C. Application of medical far infrared thermography technology in neurosurgery [Master's thesis]. Beijing: Chinese PLA General Hospital & Medical School; 2014.
32. Esselinckx W, Bacon PA, Ring EF, *et al*. A thermographic assessment of three intra-aricular prednisolone analogues given in rheumatoid synovitis. British Journal of Clinical Pharmacology 1978; 5(5): 447–451.
33. Lambiris E, Stoboy H. Thermography in osteosyntheses and total endoprostheses of the knee joint with and without infection. Zeitschrift fur Orthopadie und ihre Grenzgebiete 1981; 119(5): 521–524.
34. Baic A, Kasprzyk T, Rzany M, *et al*. Can we use thermal imaging to evaluate the effects of carpal tunnel syndrome surgical decompression. Medicine 2017; 96(39): e7982.
35. Fang Z, Shu F, Yuan S, *et al*. Hongwai rechengxiang jishu zai linchuang tengtong pingding biaozhun zhong de yingyong jinzhang (Chinese) [Advances in the application of infrared thermal imaging in clinical pain assessment criteria]. Chinese Journal of Medical Imaging 2011; 19(12): 931–934.
36. Yin X, Chen Q. Hongwai rechengxiang jishu zai zhongyi bianzheng ji bianbing zhong de yingyong xianzhuang gaishu (Chinese) [An overview of the application of infrared thermal imaging in TCM syndrome differentiation and disease differentiation]. Asia-Pacific Traditional Medicine 2018; 14(12): 80–82.
37. Yi T, Han Z, Ji Z, *et al*. Application of infrared thermal imaging in disease prevention. Infrared 2018; 39(11): 39–43.
38. Du X, Li Y, Zhou X, *et al*. Hongwai rechengxiang jishu zai zhenjiu lingyu de yingyong (Chinese) [Application of infrared thermal imaging in acupuncture research field]. Journal of Hebei Traditional Chinese Medicine and Pharmacology 2018; 33(1): 60–64.
39. Wang Y. Qingnianren tanshizhi yu pinghezhi rejiegou duibixing yanjiu (Chinese) [Comparative study on phlegm-dampness and phlegm-heat structure in young people] [Master's thesis]. Beijing: Beijing University of Chinese Medicine; 2018.