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

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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 Herschel 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 elec-
The 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 °C[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 infrared 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 99mTc-titinate 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” 192Ir 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” 192Ir source radiation accident in Nanjing.

![Figure 1. Results of infrared thermal imaging at different time after exposure.](image)
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 °C, which was 2 ~ 3 °C higher than that of the left; 30 days after exposure, the temperature in this area was 1 ~ 2 °C higher than that on the left (Figure 1a); 60 days after exposure, the temperature in this area was less than 1 °C 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 deb-ridement, 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 °C 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

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>
<thead>
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<th>Disease</th>
<th>Application</th>
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<td>Tumour</td>
<td>Breast cancer: Infrared thermal imaging technology was first applied to the early detection of breast cancer. Since 1957, through the research of Lawson[15], Williams[13], Ng[16], 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[17]. 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)[18]. 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].</td>
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<td>Cardio cerebral vessels</td>
<td>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.</td>
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<td>Inflammatory disease</td>
<td>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].</td>
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<tr>
<td>Other</td>
<td>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[19], recording temperature changes after pain and reflecting the nature, scope and degree of pain[33]. 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[34]. In 2018, Yi et al. applied it to the “prevention of disease” project of traditional Chinese medicine[35], 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].</td>
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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**


