

Clinical Usefulness of Infrared Thermography in Patients with Spinal Diseases

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Abstract: A thermal image is one kind of medical images developing since the last decades. Infrared thermography (IRT) provides information of physiological changes by detecting infrared light emitted by the body, which can be affected according to surface blood flow abnormalities of diseased areas. Symmetrical distribution of body heat is the most important element when interpreting IRT images. IRT is valuable to make diagnoses, evaluate pain with subjective complaints, and detect medical problems in various areas. We reviewed and discussed the usefulness of IRT in patients with spinal diseases. IRT is a useful tool as an adjunctive screening and diagnostic tool of spinal diseases with higher sensitivity and reliability. It is also useful to evaluate the therapeutic effect of intervention and the surgical outcomes. However, more future studies are required for high evidence on the usefulness of IRT in patients with spinal diseases. In addition, we will have an opportunity to use Thermal-Associated Pain Intensity (TAPI) as one of objective tools instead of subjective tools like numeric rating score and visual analogue score, if TAPI may be more clarified in future studies.

Keywords: Infrared light, Skin temperature, Spinal diseases, Thermography.

Abbreviations: AIS: adolescent idiopathic scoliosis, CDH: cervical disc herniation, CRPS: complex regional pain syndrome, HNP: herniated nucleus pulposus, IRT: infrared thermography, LSGB: lumbar sympathetic ganglion block, MS: multiple sclerosis, NRS: numeric rating scale, ROI: region of interest, TAPI: thermal Associated Pain Intensity, TLIVDD: thoracolumbar intervertebral disk disease, VAS: visual analogue scale, ΔT : abnormal changed of skin temperature.

1. INTRODUCTION

A thermal image is one kind of medical images that has been developing since the last decades. Infrared thermography (IRT) provides information of physiological changes by detecting infrared light emitted by the body, which can be affected according to the surface blood flow abnormalities of diseased areas [1,2]. An infrared camera detects the thermal radiation emitted by the body, and the intensity of the emitted radiation is converted to temperature [2]. The symmetrical distribution of body heat is the most important element when interpreting IRT images. The equal sized region of interest (ROI) is used for comparing the distribution of body heat on both sides, of which the difference is compared with the mean temperature within each ROI. The contralateral mean temperature

differences (between left and right sides) for a few body parts in normal subjects has been known to be 0.15°C on neck (posterior), 0.25° C on lumbar (back), 0.13° C on arm (biceps), 0.23°C on palm (medial), 0.11° C on thigh (anterior), 0.15° C on thigh (posterior), 0.30° C on foot (dorsal), 0.38° C on finger-tips, 0.50° C on toe-tips [2].

There are two methods to compare the temperature difference within an ROI of the affected and unaffected sides. The first method is to define a significant difference such as when the temperature asymmetry deviates from 1-standard deviation of ROI on the unaffected side. The second method is to define the significance such as when the mean temperature difference of ROI of the affected and unaffected sides is more than the 'difference of reference

temperature'. The latter method is usually used in the clinical area [1].

IRT is valuable to make diagnoses and evaluate pain with subjective complaints of symptoms [1,3]. The first diagnostic IRT was used in diagnosis of breast cancer in 1956, and, in 1982, the US Food and Drug Administration approved IRT as an adjunctive screening tool of breast cancer. Up to now, It has also been used to detect medical problems in various areas, such as post-herpetic neuralgia, whiplash injury, inflammatory arthritis, diabetes neuropathy, peripheral vascular disorders, complex regional pain syndrome (CRPS), and myofascial pain syndrome [1].

Common indications of IRT are 1) evaluation or follow-up of patients with known or suspected vasomotor instability, 2) assessment of patients with CRPS, 3) pre-procedure assessment for the planning of interventional therapeutics, 4) follow-up to determine the technical adequacy of surgical intervention, i.e., sympathetic block, sympathectomy, peripheral nerve implantation and/or spinal cord stimulator placement, 5) follow-up to detect improvement, progression or spread of disease, 6) evaluation of vasospastic disorders, rheumatic inflammation, and unexpected post-operative or post-fracture, 7) evaluation of sports injuries, tendinopathies, ligamentous strain, and persistent or aberrant soft-tissue pain, and etc..

IRT has been reported that it has higher sensitivity in diagnosis in patients with CRPS compared to magnetic resonance imaging or three phase bone scan, and with other neuropathic pain compared to the sympathetic skin response test. When deciding an abnormality using IRT, we should consider the adequate 'reference temperature difference' according to specific diseases, such as 0.6°C and 1.0°C for CRPS. IRT has been also reported that it has the reliability for research. Researches showed that the skin temperature differences have significant correlations with the severities of pain caused by lumbar disc herniation and the pressure pain threshold in myofascial pain syndrome [4].

However, there are still few reports with high evidence on the usefulness of IRT in patients with spinal diseases. So, we reviewed and discussed the usefulness of IRT in patients with spinal diseases.

2. DIAGNOSTIC ASPECT OF THERMOGRAPHY ON SPINAL DISEASES

2.1. Whiplash Injury

Whiplash injuries as well as cervical spine soft tissue injuries are a common medical problems after rear-end automobile collisions due to sudden forward and backward movements of the head. Unfortunately, it is difficult to visualize the subjective painful experience secondary to these injuries and the symptom, and there is no diagnostic tool to objectively demonstrate these symptoms yet. Recently, Lee et al. [5] suggested that IRT can be a reliable objective tool to visualize the subjective symptoms of whiplash injury as well as the clinical improvement after treatment. The immediate skin temperature of the neck and shoulder just after injury showed 1-2 °C higher temperatures than normal, and it was gradually near the normal value after two weeks. They also showed that the changes of in the thermal differences were highly correlated with reduced visual analogue scale (VAS) after treatment.

2.2. Radiculopathy

IRT is valuable as a complementary tool for diagnosis of unilateral spinal radiculopathy, because vasomotor dysfunction caused by irritation or damage of the spinal nerve root leads to abnormal changes in skin temperature of the affected extremity.

In the case of radiculopathy due to cervical disc herniation (CDH), subjective symptoms of upper extremities such as cool or warm sensation can be shown objectively by using of IRT with the detection of thermal change. Furthermore, the areas of thermal change in CDH can be helpful in diagnosing the level of disc protrusion and in detecting the symptomatic level in multiple CDH patients with the minimal abnormal thermal difference in the right and left upper extremities ranged from 0.1°C to 0.3°C according to sensory dermatome and sympathetic dermatome [4] . However, IRT is not useful to diagnoses the patients with neck pain and mild disability, because it do not present with reduction or asymmetry of upper trapezius muscle temperature compared with patients without neck pain [6].

In case of thoracolumbar disease, there is no reference in clinical study except of animal study. The animal study showed that IRT was related with 90% success in differentiating normal dogs from dogs affected by

thoracolumbar intervertebral disk disease (TLIVDD), and 97% success in identifying the abnormal intervertebral disc space in dogs with TLIVDD [7]. However, the ROI mean temperature analysis did not identify the successful abnormal intervertebral disc space localization.

In the case of lumbar radiculopathy, 97% of the patients showed abnormal changed of skin temperature (ΔT) in at least one of 30 ROIs, and hypothermia on the involved side was shown in 79% of these patients, while neither pain severity nor other physical or electrophysiological findings were related to the IRT findings [8]. However, some studies suggested that the severity of the clinical manifestation of radiculopathy had a correlation with temperature differences between the symmetrical parts of the lower extremities. IRT showed a significant thermal deficit ($\Delta T > 1^\circ\text{C}$) in the affected lower extremity in at least one out of four recorded ROIs, and this thermal deficit was strongly correlated with pain intensity, mobility of the lumbar spine, and functional status of the patient [9]. Takahashi et al. [10] also suggested that thermal deficit detected by IRT should be considered as an independent sign of lumbar radiculopathy, of which the symptomatic severity may be assessed by the magnitude of thermal deficit in the affected extremity with the relatively high specificity (80%).

The skin temperature changes in thigh, posterior femur area, and plantar surface of affected side are highly correlated with lumbar radiculopathy and low back pain, but it was not on the lumbosacral region [11-13]. So, the symptoms of myelopathy, radiculopathy can be detected easily by the IRT, but local pain was not well visualized [14].

2.3. Post-Sympathectomy Dysfunction

Lumbar sympathectomy can results from the anterior lumbar interbody fusion and extreme lateral interbody fusion to the lumbar spine, which are sometimes necessary to sacrifice the lumbar sympathetic chain. So, after these surgical procedures, post-sympathectomy dysfunction can be showed with the incidence of 1% to 43%. For evaluation of post-sympathectomy dysfunction, IRT can be used with 1.0°C or more as cut-off value because the temperature difference is $0-0.9^\circ\text{C}$ in patients without sympathectomy [15].

2.4. Adolescent Idiopathic Scoliosis

Adolescent idiopathic scoliosis (AIS), a multifactorial, three-dimensional deformity of the spine and trunk, can be used for early detection of AIS to prevent its progression by the use of IRT on the asymmetrical para-spinal muscle activity [16]. Scoliotic patients demonstrate a significant temperature difference of ROI between the left and right side. This difference could be due to the higher infrared emission of the convex side of the observed area, creating a higher temperature distribution [16]. If the difference in the value of the cut-off temperature is set at 0.3°C , the infrared camera and analysis software are able to detect 12 out of the 17 cases of scoliosis. As the infrared camera is sensitive enough to detect temperature differences up to 0.07°C , the cut-off value can also be adjusted to a very precise level of differentiation.

2.5. Multiple Sclerosis

Multiple sclerosis (MS) is still one medical mystery; it is not avoidable or curable and has broad symptoms, especially chronic pain and inadequate thermo-regulation, which directly interfere with quality of life of patients. Patients with MS may show Uhthoff phenomenon, worsening of symptoms due to exposure to temperature higher than normal, and Lhermitte signal, sensation of electric current irradiating through the spine when binding the neck. For being a very broad differential diagnosis and having a variety of symptoms, IRT may be used with temperature differentials above 0.3°C . A recent literature review recommends the use of thermography in the clinical practice in patients with neurological disorders, where it may be used as auxiliary diagnostic tool or as method for clinical follow up of the disease. Papaléo et al. [17] documented that IRT has shown asymmetry of the whole right hemibody with central neurogenic patterns and temperature difference ($\Delta T 0.8^\circ\text{C}$), thus they could confirm initial diagnosis in patients with MS in crisis of pain.

3. THERAPEUTIC ASPECT OF THERMOGRAPHY ON SPINAL DISEASES

IRT is useful to evaluate the effect of therapeutic intervention as well as diagnose the spinal diseases. The increase skin temperature of affected lower extremities can be considered as a successful effect after a lumbar epidural block [18]. In patients undergoing thoracic paravertebral blocks, Thermographic images are

correlated with the large unilateral somatic and sympathetic blocks, which are evidenced by ipsilateral skin warming as successful blocks [19].

IRT is a useful method for representing the success of a lumbar sympathetic ganglion block (LSGB). IRT showed the most significant skin temperature changes (ΔT s) at the plantar (6.2°C) and dorsal surfaces of the feet (3.9°C) following a LSGB [20]. So, Kim et al. [20] suggested that an evaluation of the ΔT s on the plantar surface of the feet is the most effective, safe, and simple method for assessing whether LSGB is performed successfully.

Wu et al. [21] also suggested that IRT objectively showed the decrement of surface temperatures correlating with changes in subjective pain intensity in the 12-week follow-up after manual medicine therapy of coccygodynia, and it is useful as a quantifiable tool for monitoring the dynamics of the disease activity.

IRT can be used for evaluation of surgical outcome and determination of optimal physiotherapy as rehabilitative interventions after surgery for herniated nucleus pulposus (HNP). A lower temperature of plantar surface on the affected side in patients with HNP was recovered after surgery [22]. However, after surgery, infrared image patterns did not normalize 10 weeks after surgery [7].

IRT can be used for investigation of skin temperature changes after the endoscopic thoracic sympathectomy in patients with hyperhidrosis [23]. The palmar skin temperature is significantly lower (1.3°C) than the facial temperature before sympathectomy, and its variations among patients are much greater preoperatively than postoperatively. The temperatures of the thenars, palms, digits, and nose are significantly increased after sympathectomy, but that of the forehead, mandible, or neck is not. Especially, more prominent postoperative palmar skin temperature elevation is related with lower preoperative palmar skin temperature. Chuang et al. [24] also suggested that intraoperative palmar skin temperature monitoring provides the useful information about the targeted sympathetic segments and confirmation of entire successful ablation by endoscopic thoracic sympathectomy at postoperative 6 months follow-up period.

4. THERMOGRAPHY IN PAIN ASSESSMENT

Interestingly, Recently, Czaplik et al. [25] introduced "Thermal-Associated Pain Intensity" (TAPI) as new one of pain assessment tool, and they reported that TAPI correlates significantly with the numeric rating scale (NRS) with a sensitivity of above 0.75 to detect pain. So, if TAPI may be more clarified in future studies, we will have an opportunity to use TAPI as one of objective tools instead of subjective tools like NRS and VAS.

5. CONCLUSIONS

IRT is a useful tool as an adjunctive screening and diagnostic tool of spinal diseases with higher sensitivity and reliability. It is also useful to evaluate the therapeutic effect of intervention and the surgical outcomes. However, more future studies are required for high evidence on the usefulness of IRT in patients with spinal diseases. In addition, we will have an opportunity to use TAPI as one of objective tools instead of subjective tools like NRS and VAS, if TAPI may be more clarified in future studies.

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