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Infrared thermographic evaluation of patients with metastatic vertebral fractures after combined minimal invasive surgical treatment

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Abstract

Background: Vertebral cement augmentation and external beam radiotherapy have become increasingly used techniques for treatment of vertebral compression fractures due to spinal metastatic lesions in the Republic of Moldova. Surgically, the goal of vertebral cement augmentation is to improve the strength and stability of the injured vertebrae, as well as local tumor control. External beam radiotherapy for suppressing tumor or inducing pain relief are performed immediately after vertebral cement augmentation. Usually, local tumor control is occurred by CT or MRI studies. We have studied through the infrared thermography the dynamics of temperature gradient of tumoral foci skin projection.

Material and methods: The purpose of this study is to evaluate the local tumoral control, analyzing the infrared thermographic examinations in 33 patients with uncomplicated metastatic vertebral fractures, undergoing combined method of treatment (vertebral cement augmentation + external beam radiotherapy), before the treatment and at 12 months follow-up.

Results: We observed an indirect tumor "thermographic field" decrease registered by temperature gradient decrease from an average of 2.03±0.24ºC in preoperatively to 1.28±0.33ºC at 12 months postoperatively follow-up.

Conclusions: Combined method of stabilization (vertebral cement augmentation + external beam radiotherapy) in patients with uncomplicated metastatic vertebral fractures is effective in minimal invasive surgery and offering local tumor control.

Key words: spinal metastases, pathological fractures, vertebral cement augmentation, radiotherapy, infrared thermography.

Introduction

Historically, temperature has been proved to be a very good indicator of health [4, 5. 8]. Human, being a homeothermic mammal, is capable of regulating deep body temperature within a narrow range through a number of behavioral, metabolic and physiological processes. In this order, the entire homeothermic body can be divided into two parts: the inner core and the outer periphery. The human inner-core normal temperature is preserved within a narrow limit (approximately 36.2–37.5°C), regulatory mechanism being essential for normal functioning of all biochemical ways. In this regard, any change of core and peripheral temperature, by a few degrees in the same conditions, is considered as a clear sign of probable illness [2, 3, 7].

The first report of cutaneous temperature changes is described by Hippocrates and later by ancient doctor Celsius (Celsian signs). In 17th century, physician George Martin first used the thermometers to measure diurnal changes of temperature in normal subjects. In 19th century, Carl Wunderlich published his report, where he described temperature as a scientific indicator of illness. In 1800 was discovered, by Sir William Herschel, infrared radiation followed by the recording of the first thermal image, which opened new dimensions in the field of temperature measurement. Hardy, in 1934, described the physiological role of infrared emission from human body and proposed that human skin can be considered as a thermal radiator and established the diagnostic importance of temperature measurement by infrared technique which paved the way for using infrared thermography in medical sciences. But, the first use was reported just in the 1960, because of non availability of special quality equipment [1, 6, 7].

Infrared thermography (IRT) is a non-contact, and therefore remote, method of measuring the surface temperature of objects. All objects with temperature above absolute zero emit electromagnetic radiation, which is known as infrared radiation or thermal radiation, within a range of 0.75–1000 μm. The infrared emissions from human skin at 27°C lie within the wavelength range of 2–20 μm. It peaks around 10 μm. For medical applications, we use a very narrow wavelength band (8–12 μm). As per usual, the first modern infrared detector was originally developed for military applications [5].

The IRT examination of irregular objects surface causes abnormal thermal patterns, which indicate the presence of those defects. Similarly in clinical practice, the illness causes abnormal thermal patterns on the skin surfaces. In 1963, Barnes demonstrated that thermograms can provide information of physical anomalies and thereby be useful for diagnosis of physical illness [3, 6, 8, 9].

Material and methods

We analyzed the IRT imaging, in a group of 33 patients with uncomplicated metastatic vertebral fractures, undergoing combined method of treatment (vertebral cement augmentation + external beam radiotherapy), before the treatment and at 12 months follow-up. For IRT imaging we used the portable hardware ИРТИС-2000 МЕ™. This device has been specially designed for use in medical practice, with a spectral range between 3-5μm, and a thermal range from -10°C to 170°C, with sensitivity in the field of examination of 0.02°C and accuracy of ±0.5°C.

The distance and angle of the subject to the camera have profound effects on the accuracy and precision of temperature measurement by IRT. In our study the IRT examination

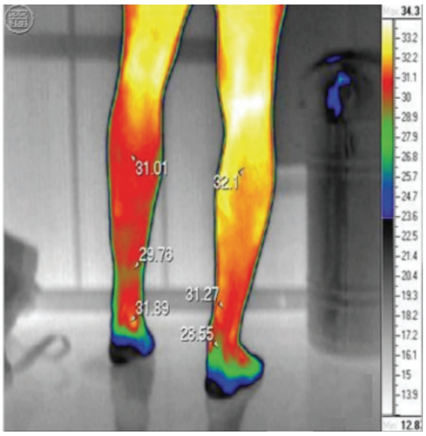

Fig. 1. Patient with breast carcinoma and L_{III} metastatic vertebral collapse with symptomatic radicular dysfunction.

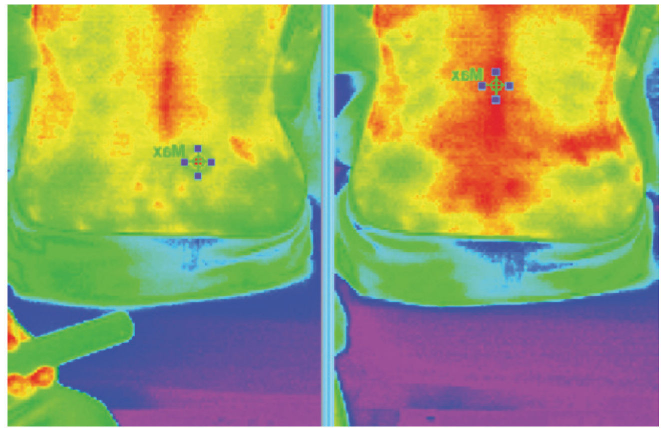

Fig. 2. Patient with prostate adenocarcinoma T2N0M1 and Mt in LIII treated by external beam radiation therapy. Actinic dermatitis (at 1 month follow-up).

was carried out in a room about 20m^2, with a temperature control about 20-24°C, convection and air leakage rate less than 0.4m/s and relative humidity 50-75%, in a comfortable position for the patient. For patients with severe static and dynamic disorders sitting in the chair or horizontally it was possible to record. The distance between the patient and analyzer was about 2-2,5m. The first record of IRT occurred after patient's adapting with room environment (average 10 minutes). It was registered thermal field over the tumoral locus in the spine, at the spinous line. If on the patient was observed any neurological disturbance, we registered thermal schedule over paravertebral lines and limbs. To appreciate the difference in temperature between the thermal projection of the vertebral tumoral locus and other anatomical regions of the examined patient was established standard thermal schedule or physiological status.

As a physiological status of the investigated patient served arithmetic average of IRT registered temperatures in eight different symmetrical anatomical regions of the body, in two points on the thorax and abdomen, respectively, and four points on the back. To determine the thermal activity (aggressiveness) of the metastatic locus in the vertebral segment, or severity of neurological deficits, we estimated stroke IRT. This is a functional pharmacological active test, registered after 30 minutes of sublingual administration of five pills of glucose with vitamin C. At the same time, we must keep in mind that, in the elderly it was impossible to rule out the influence of preexisting degenerative changes of the spine or peripheral vascular disorders on thermographic picture of the patient.

By these reasons, for the analysis and the correct description of the results obtained in the examination of the IRT, we used three basic principles:

- Thermo-morphological – describing the anatomy of the hyperthermic locus: location, shape, surface, contour, uniformity;
- Thermo-functional – represented by difference between background temperature and provoked temperature range of the tumoral locus, or body thermoasymmetry (with temperature gradients definition);
- Thermo-regulation – functional tests were used for assessing the dynamics of thermal changes in tumor foci.

After the IRT examination was calculated temperature gradient (TG) by using the accompanying software of ИРТИС-2000М™, which represents the difference between the maximum temperature (t°C) of the tumor field and standard thermal regime of the patient.

Results

Preoperative evaluation of patients in 100% cases revealed a typical thermal syndrome. It was represented by a clear hyperthermic area in tumoral field (over 1.5-2°C) with homogeneous irregular contour, sometimes asymmetrical, located in the projection of the vertebral tumor foci. In patients with symptomatic radicular syndromes, "root strips" were observed, represented by hypothermia zones on the affected limb as compared to the healthy limb (fig. 1).

After minimal invasive surgical treatment of collapsed vertebrae, we determined the thermo-functional characteristics of tumoral foci and limbs and we observed in follow-up the dynamics of TG after undergone therapy (fig. 2).

The efficacy of applied combined surgical treatment was tested in follow-up – before and after surgery at 1, 6 and 12 months. Were considered as positive results of the applied treatment the situations where the hyperthermic areas of tumor foci appear through a "model of extinction" in follow-up or hypothermic zones of limb occur through temperature normalization. In the absence of positive dynamics, we can consider tumor resistance or inefficiency of practiced method of treatment, which requires radical therapeutic model changes.

Thereby, after TG values registration, we obtained the values of temperature gradient in tumoral foci: before treatment – 2.03±0.24° [1.6°; 2.5°]; at 1 month – 1.98±0.3° [1.5°; 2.8°]; at 6 months – 1.55±0.28° [1.1°; 2.3°]; at 12 months – 1.28±0.33° [0.8°; 2.3°] (fig. 3).

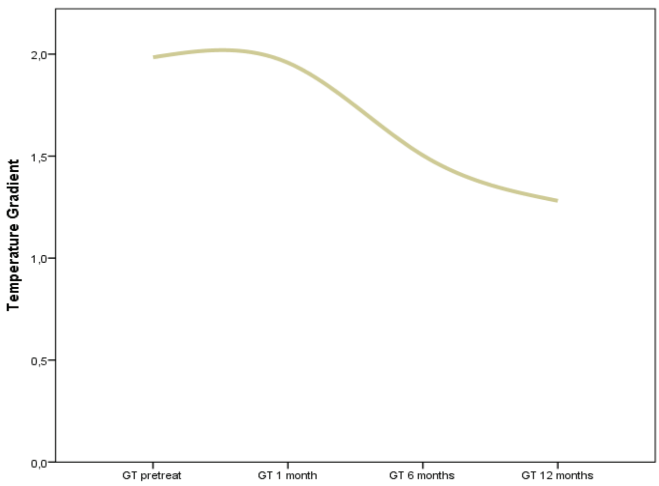

Fig. 3. Temperature gradient evolution in follow-up period.

Analyzing the data presented in figure 3, we observe that after applied combined method of minimal invasive surgical treatment, there is a general improvement of temperature gradient in tumor foci with -0.7±0.26° at 12 months.

Discussion

The human body's temperature is maintained constantly by a sophisticated thermoregulatory center in the hypothalamus. Thermoregulation is impaired in sick patients. IRT indicates the temperature pattern to identify an abnormality. Hence, there is no radiation risk as it captures the infrared radiation from the skin and is totally painless. Based on this idea, thermography was developed and first used for the diagnosis of breast cancer.

Because of its accuracy, low risk, and noninvasive nature, IRT should be employed as a cost-effective initial screening procedure to distinguish between patients with substantive radicular disorders and those experiencing minor localized injury. IRT is a test advocated by some physicians and chiropractors for diagnosing disk abnormalities.

Usually analysis of the thermograms of patients showed regional hyperthermia in the spinal pathology field and hypothermia in affected lower limb. The combination of local (spinal) and distant (peripheric) thermoasymmetries, which are realized through reflex mechanisms of vegetovascular innervation, is a characteristic feature of the thermovision syndromes in IRT examinations in patients with spinal disorders. The mechanisms of the origin of thermoasymmetry are discussed. For example, malignant cancerous lesions (neoplasms) develop high metabolism and use more blood supply than normal tissue. A comparative estimation of different methods in the differential diagnosis indicated the advantages of IRT. Several studies have found good to excellent reproducibility for paraspinal thermal scanning using a variety of devices [12-14].

Infrared thermography has become a reliable clinical technique used to measure body temperature and indicate noninvasively the presence of cancerous diseases. From these reasons, IRT can detect temperature changes during spinal diseases, also vertebral tumors.

This abnormality in temperature distribution might indicate the presence of an embedded tumor. Although, IRT currently is used to indicate the presence of an abnormality, there are no standard procedures to interpret these and determine the location of an embedded tumor [15-17].

Our research focused on the spinal tumoral field evolution before treatment and in follow-up. The temperature emitted from the skin visualized on the screen in the form of contoured color spectrum - blue, yellow, green and red - depending on "thermal activity" of vertebral metastases. The regional thermal deficit of the affected lower limb did not follow the specific dermatome. A possible explanation of this clinical finding is that blood supply of the skin in the lower extremities is different to the neural sensitivity in the same areas.

Studies on the application of thermography in spinal metastases management are scarce, and there are no studies of thermal changes during vertebral metastases evolution after cement augmentation. This research is a first step towards IRT examination outcomes of patients with spinal metastases after minimal invasive surgical treatment.

The main limitation is the absence of a control group. In future research, we will consider this. We believe that it has not significantly affected our results, because we analyze the absolute value of the temperature, but not the temperature difference between the two sides of the lower extremities.

Conclusions

By detecting cutaneous temperature changes in the tumoral foci, fracture level and limb, infrared thermography offers another non-invasive, contrast-free option in functional assessment of treatment outcomes. Percutaneous vertebral cement augmentation is a minimally invasive procedure and, when combined with radiotherapy, is effective in providing a local tumoral control.

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