Application of Thermal Imaging for Early Diagnostic of Maxillofacial Pathology

R. Adaškevičius[1*], V. Krasnickaitė[1], D.Mačianskytė[2]

[1]*Kaunas University of Technology, Lithuania*

[2]*Lithuanian University of Health Sciences, Lithuania*

[*]*E-mail: rimas.adaskevicius@ktu.lt*

Introduction. Thermal imaging is a technique of detecting the objects' infrared radiation and creating an image based on that information, but it is not widely used in routine medical diagnostics. The first utilizations of thermal imaging were made with large and noise scanners in 1956. In ours days thermography is broadly used for diagnostics of breast cancer, skin melanom and other areas of pathology.

Thermal imaging captures the natural thermal radiation generated by an object at a temperature above absolute zero. It is non-invasive, non-contact, passive and radiation – free technique. Clinical application of thermography is based on the ability to image natural heat emissions of the human body. It is based on the principle that the temperature of the area surrounding the damaged, prie-cancerous and cancerous tissue is higher than that of a normal tissue. For a normal person, the thermogram shows uniform and symmetric temperature variations. In case of abnormality, pathological regions show aprupt variations in temperature [1, 4].

The objectives of the study is to evaluate the potential of thermography in diagnosis of the disease of human jaw.

Materials and methods. Thermal imaging is a technique for temperature measurements based on the infrared radiation from objects. The radiance from human skin is an exponential function of the surface temperature, which is influenced by the level of blood perfusion in the skin. Unlike images created by x-rays or proton activation through magnetic resonance, thermal imaging is not based on morphological analysis. The technique provides only a map of the distribution of temperatures on the surface of the subject imaged. So, to determine whether a local abnormality in tissue temperature is present or not the special image processing approaches for extraction of the features of thermal images must be used.

The proposed method for thermal imaging analysis for early diagnostic of maxillofacial pathology comprises the following steps:

1) The acquisition of thermal data;
2) Pre-processing of thermal images;
3) Examination of paired (right and left) areas of face surface and paired intraoral areas;
4) Segmentation of thermal image;
5) Evaluation of diagnostic accuracy by comparing results from thermal imaging with computer tomography findings.

Before the measurements, the subjects were thermo-equilibrated in the laboratory space for 15 minutes [2]. The room temperature was maintained by a wall mounted air conditioning unit and was in range between 20 °C and 22 °C. The air conditioning was switched off during measurements and there was no direct sunlight. The subjects were instructed to sit up as straight as possible.

The face region being investigated by an infrared thermal camera was positioned one meter away from subject. Thermal imaging was carried out using a thermal camera FLIR E8 (thermal sensitivity – 0.06 °C, resolution – 320 × 240, the maximum temperature range from - 20 °C to + 250 °C). For each of subjects facial thermal images were taken using frontal projection, right and left lateral projections, and mouth‘s cavity. Each surface temperature profiles of the patients were recorded and later analyzed using image processing software in Matlab.

Thermal images transformed into Matlab readable data files by ThermaCam Researcher 2.1. Each image must carry the information about temperature range, emissivity of body, atmospheric temperature and relative humidity, distance from human to camera.

The pre-processing of thermal image starts from checking of thermal data structure: the parameters representing environment conditions, the distance from patient to camera, emissivity of body must be in the correct range. The next step after checking of integrity of thermal image is to detect edges of human face. For edge detection the gradient image was created from the original thermal image. Each pixel of a gradient image measures the change in intensity of that same point in the original image, in a given direction. After gradient images have been computed, pixels with large gradient values become possible edge pixels. The Prewitt method was used to find edges using the Prewitt approximation [3]. It returns edges at those points where the gradient values are maximal. The Prewitt method was selected for its simplicity and its low computational load.

For presentation of human face external contour as smallest convex polygon that contains all the points of edge, the convex hull was calculated. The convex hull of an edge image is the set of pixels included in the smallest convex polygon that surround all edge pixels and was used to describe the external boundary of field, which temperature changes were analysed.

Thermal imaging is hence well suited to pick up changes in blood perfusion that might occur due to inflammation or other causes. Asymmetrical temperature distributions as well as the presence of hot and cold spots are known to be strong indicators of an underlying dysfunction [4]. Thermal symmetry in the face is a normal finding in healthy subjects. The best fitting for an ellipse from set of convex hull vertices was used for identification of axis of face symmetry. The Least-Squares criterion for estimation of the best fit to an ellipse from a given set of points was used. So, the major semi axis of ellipse represents an axis of symmetry of human face. It was used for splitting the field of analysis into two independent areas. The average temperatures of left and right sides of human face were calculated and compared. The temperature asymmetry higher than 0.4 ^{o}C

[1] was associated with the presence of abnormality and additional investigation for identification of abnormal regions is necessary. In the same order the mouth cavity was investigated and temperature asymmetry evaluated.

For representation of pathological region additional right or left side thermal images were used. The appropriate side image was used for calculation of isolines along which the temperature has a constant value. The number of isolines and the values of the isolines are chosen automatically based on the minimum and maximum temperature values of face area. A filled contour plot for displaying of isolines and filling the areas between the isolines using constant colors corresponding to the current temperature color map is representative tool for evaluation of abnormality of face region. The abnormal region has different temperature and it can be highlighted in different color from the rest of the face. The location of abnormality, identified using thermal imaging was compared with results of computerized tomography (CT).

Results. The thermograms were collected from 6 patients (3 patients with a tumor, one patient with an inflammatory origin of jaw and 2 healthy persons) using non-contact thermography at the Clinic of Radiology, Lithuanian University of Health Sciences. All patients additionally were investigated with CT Toshiba „ONE Aquilion“. The average and standard deviation of temperature measurements taken using frontal face and mouth’s cavity projections were calculated from 5 measurements in each image and the results are shown in Table 1.

Table 1. Thermographic analysis of frontal regions face and mouth’s cavity

		Patient 1	Patient 2	Patient 3	Patient 4	Patient 5	Patient 6
Righ Side, T ^{o}C	Face mean ± SD	33,51 ± 0,017	33,77 ± 0,032	32,93 ± 0,01	31,884 ± 0,015	34,49 ± 0,038	33,68 ± 0,039
	Mouth’s cavity mean ± SD,	37,44 ± 0,0217	38,67 ± 0,017	35,85 ± 0,0618	33,445 ± 0,0243	36,412 ± 0,0192	35,07 ± 0,013
	Highest temperature	38,34	39,23	36,13	34,23	37,13	36,18
Left Side, T ^{o}C	Face mean ± SD	34,37 ± 0,019	33,93 ± 0,054	32,85 ± 0,015	31,35 ± 0,018	34,32 ± 0,013	33,59 ± 0,04
	Mouth’s cavity mean ± SD	38,08 ± 0,0234	38,23 ± 0,01	35,85 ± 0,085	32,95 ± 0,0221	36,252 ± 0,0286	34,894 ± 0,023
	Highest temperature	38,98	38,85	35,03	34,53	36,91	36,05

In case of tumor in maxillofacial region (Patient 1) in pathological field of face thermal image the higher temperature area due to hyper vascularity of tumor tissue was detected. The asymmetry of average face temperature was 0.76 ^{o}C. In case of tumor in maxillofacial region (Patient 2), the asymmetry of average face temperature can be small and the location of tumor was evaluated by calculating temperature asymmetry of mouth’s cavity (asymmetry is 0.44 ^{o}C). The pathological area is highlighted in different color (Fig. 1). In case when the tumor was localized deep in mouth's cavity, in oropharyngeal region, the average temperatures between left side and right side of face or mouth’s cavity do not differ (Patient 3). So, the highest temperatures of different sides must be compared. In case of inflammatory (Patient 4), the abnormal area was successfully identified, but the temperature in this area was lower than in other fields of face. The significant difference in thermal symmetry of the face or mouth's cavity images was not found for healthy persons (Patient 5, Patient 6).

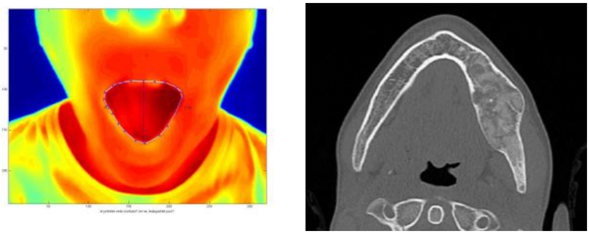

Fig. 1. Thermo graphic image of patient face with tumour (abnormal area highlighted in dark red in mouth cavity) and CT image of tumor

Conclusions. The proposed method can be used for medical diagnostic of maxillofacial pathology. Temperature gradients are observed in the affected regions of patients, indicating abnormal blood flow in the affected region, which is well correlated with the CT findings. The temperature in the affected regions was about 0.45-1.1 ^{o}C above the normal regions. Results of this work indicate that detection of maxillofacial pathology using thermal images shows a great promise in helping to develop an objective screening tool in the near future.

References

1. Durnovo E.A., Potekhina YU.P., Marochkina M.S., Khomutinnikova N.E., Yanova N.A. Features of Infrared Thermography in the Diagnosis of Complex Diseases of Maxillofacial Region // Modern Problems of Science and Education, No 4, 2012.
2. Rajendra Acharya U., Ng E.Y.K., Vinitha Sree S., Chua Kuang Chua, Subhagata Chattopadhyay. Higher order spectra analysis of breast thermograms for the automated identification of breast cancer //Expert Systems, February 2014, Vol. 31, No.1. –P. 37 - 47.
3. Shrivakshan G.T. A Comparison of various Edge Detection Techniques used in Image Processing // IJCSI International Journal of Computer Science Issues, Vol. 9, Issue 5, No 1, September 2012. –P. 272 - 276.
4. Mostovoy A. Thermography and Oral Pathology // EAT2012 Book of Proceedings – Appendix 1 of Thermology international 22/3, 2012. –P. 159 - 161.

Application of Thermal Imaging for Early Diagnostic of Maxillofacial Pathology

R. Adaškevičius[1], V. Krasnickaitė[1], D.Mačianskytė[2]
[1]*Kaunas University of Technology, Lithuania*
[2]*Lithuanian University of Health Sciences, Lithuania*

We present a method for diagnostic of maxillofacial pathology using thermal imaging. It is based on the principle that the temperature of the area surrounding the damaged, prie-cancerous and cancerous tissue is higher than that of a normal tissue. It was found, that face surface temperature asymmetry higher than 0.4^{o}C was associated with the presence of abnormality.