Histographic Method as a Tool of Thermal Image Processing

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SUMMARY

Among essential values characteristic of the histograms, the following are selected: the highest (maximum), the lowest (minimum) and the average temperature in the defined area; the median, standard deviation and skewness; the number of pixels in the examined area and the maximum value on the ordinate of the histogram. The distribution curve D of the histogram is the integral of the histogram and the derivative dD/dt of the distribution curve gives the shape of the histogram.The series of distributions of histograms is more visual and efficient for comparisons than a series of histograms. For illustration, figures are taken from the effects of β irradiation.

1. INTRODUCTION

It is an experience that ionising radiations produce thermal effects in human organisms. Nevertheless, very few data are available on the quantitative relationship of the dose of ionising radiation and the changes of temperature. The studies were planned, therefore, to reveal the thermal detectability of tissue reactions following radiotherapy treatments. By this way during the radiation treatments the thermal measurements made possible to detect the sequential alterations in the thermal map of the involved body surfaces.The thermal studies were performed in collaboration with the National Institute for Oncology by measurements of patients irradiated with beta rays. In the paper the results of infrared thermogrammetry investigations are given by histographic method.

2. ANALYSIS OF TEMPERATURE DISTRIBUTION BY HISTOGRAPHIC PROCESSING

Histographic analysis is the usual mode of processing experimentally and otherwise obtained sets of data, but it may be considered as an efficient way for describing temperature fields, too. Thereby there is still little experience available for such applications and for the proper evaluation all of histogram characteristics (4, 6, 9).

In histograms which represent temperature fields of digital IR-images, pixel numbers (in percentage) with the given temperature are plotted against temperatures occurring within the fields (e.g. Fig. 1). Temperatures occurring in the selected area may be displayed both more simple: graphically (Figs.7, 8 and 9) and more sophisticated: digitally (Figs. 3 and 6), and the obtained data lend themselves for further computations. In our practice satisfactory results were obtained when the temperature varied by tenths of degrees within the range.

Among essential values characteristic of the histograms, the following are pointed out: the highest (max), the lowest (min) and the average (avg) temperature in the defined area; mediane (med), standard deviation (Sdev) and skewness (Skew) (Fig. 3); number of pixels in the examined area (Ncal) and the maximum value on the ordinate of the histogram (Fmax).

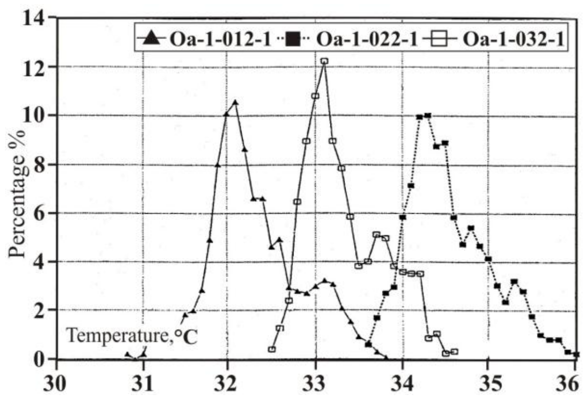

Fig. 1 - Series of histograms of the temperature values of the β-irradiated areas on the first (▲), second (■) and third (⊟) day during radiation treatment (first week).

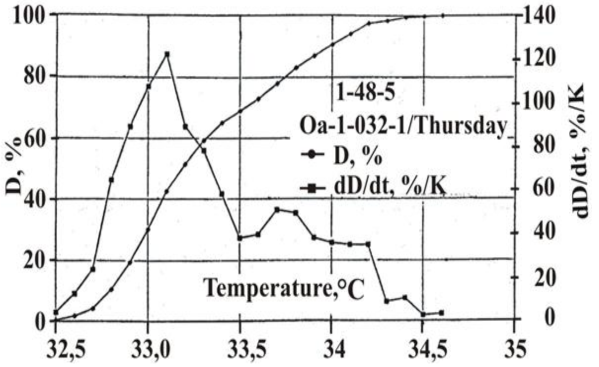

Fig. 2 - The distribution of a temperature histogram *D* and its derivative *dD/dt*, i. e. the shape of the histogram (after the second session).

3. BIOLOGICAL INDICATORS OF THE RADIATION EFFECT

In case of an injury or a radiation treatment the amount of blood circulating through the region during irradiation is too small to contain enough lymphocytes to use them as carriers of chromosome aberrations. At the same time the local tissue reactions might be used to measure the effect of irradiation. Out of the cells of irradiated skin and subdermal tissues the endothelial cells covering the inner surfaces of vessels and representing the walls of capillaries are the most radiosensitive ones. The radiation causes first the dilatation of vessels, then due to the damages of capillaries and vessels the atrophy and necrosis of the tissues (Figs. 7, 8 and 9). The conditions of the vessels and the consequent tissue alterations can be followed by radioisotopic scintigraphy or through image formation by thermogrammetry (1, 2, 8).

4. METHODS OF EXAMINATION

The investigations on the beta-irradiated chest was performed by AGA THV 780 type infrared imaging equipment. The results of measurements were stored from the different investigations, during three weeks (Fig. 5) by an infrared video recording which was evaluated by computerised technique (Fig. 3, in a colour plate)

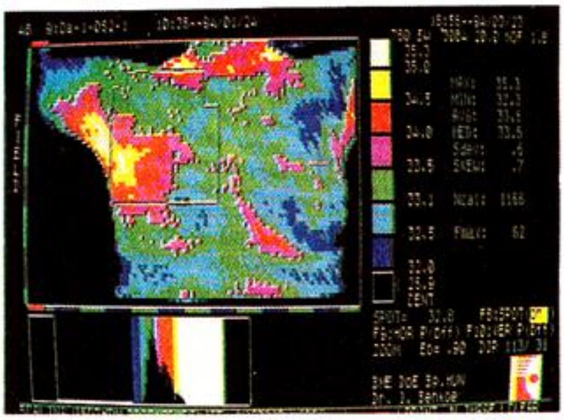

Fig. 3 - Infra-red thermogram of female chest on the 7th day (after 5 sessions, No. 052) evaluated by computerized histographic method.

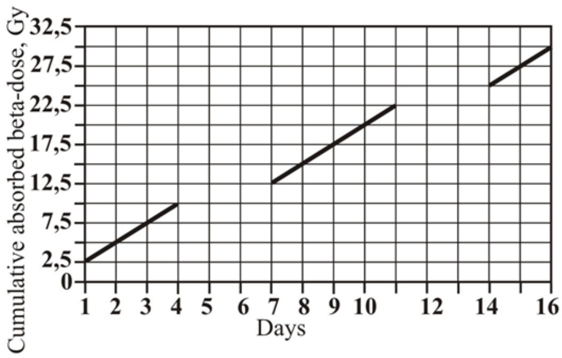

Fig. 5 - Cumulative absorbed beta-dose values during the treatment

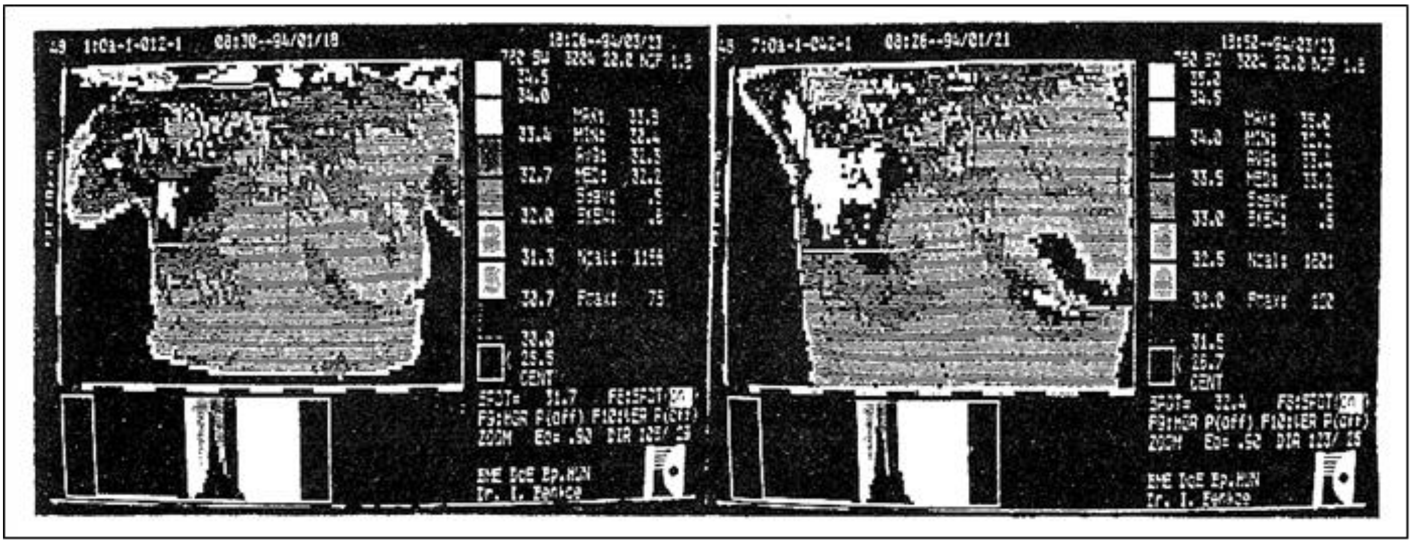

Fig. 6 - Infra-red thermograms of female chest before (left figure) and on the 4th day during radiation treatment (right figure), evaluated by computerized histographic method.

3.1 More simple data presentation

Skin temperature has been used as an indicator of the physiological and pathological condition of the human body for centuries. The infrared (IR) thermogrammetry (TGM) / thermography gives new vistas for the transient skin surface temperature measurements, too. IR-TGM can also be advantageously applied in radiation biology for comparative and quantitative diagnostic investigations. In Hungary, the technique was first applied in 1984, when the authors published a case study on a local radiation injury (4) and suggested that both contact and infrared thermography were useful tools in detection of the areas of radiation injury. While in 1984 a serious injury of a hand (20-30 Gy, locally) was described, later (3, 8) an injury caused by a much lower dose (1-2 Gy, locally) is reported when IR-TGM could still assist the diagnosis. The measurement results obtained enabled the authors to compare the radiation burden and the temperature distribution detected at the involved skin surface.

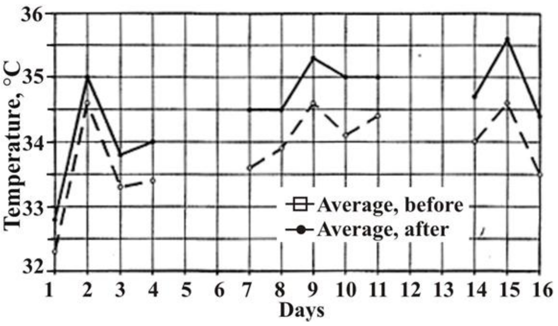

Fig. 7 - Immediate changes of the average temperatures on the irradiated surfaces before and after each radiotherapy sessions

The method of data analysis was elaborated and applied for the investigation of six patients. The irradiated areas as shown on Fig. 4 have absorbed 2.5 Gy at each session but from various energies. The radiation treatment was performed through three consecutive weeks, 5 irradiation sessions per week applied daily (Fig. 5), the beta-dose was 12 times 2.5 Gy. The treatments on week-end days were omitted.

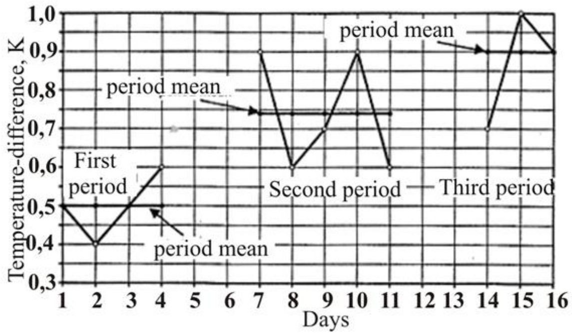

Fig. 8 - Changes of average temperature differences as measured before and after radiotherapy sessions during the treatment (based on Fig. 7).

The immediate effect could be seen already 20-30 minutes after irradiation (Figs. 7, 8 and9). These post-operative irradiations always complete the complex therapy of breast cancer patients.
We can observe the immediate changes of the surface temperature because of the radiation treatment and Fig. 7 shows the average temperatures changes on the irradiated surfaces before and after each radiotherapy sessions.
On the base of Fig. 7 we can calculate the changes of average temperature differences as measured before and after radiotherapy sessions during the treatment (Fig. 8).
The fluctuation's process of the field of temperature can be present by Fig. 9 showing the changes of average temperature values of irradiated area before and 24 hours after each irradiation in function of the cumulative absorbed beta-dose.

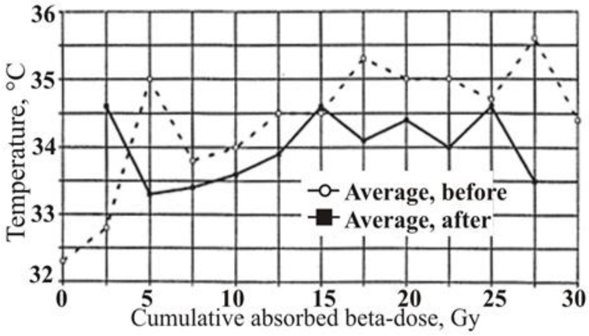

Fig. 9 - Changes of average temperature values of irradiated area before and 24 hours after each irradiation in function of the cumulative absorbed beta-dose.

3.2 Presentation of effects of radiation treatment

The following information can be obtained and this is important for medical application:
(a) the detection of injuries mainly in comparison with the relevant contralateral part of the body;
(b) visualization of the extent of the injury and;
(c) the possibility of follow-up of the pathological condition.

In determining the temperature fields of various characteristics, the choice is between the following general methods, while their relative advantages and disadvantages must be decided in the light of the test being performed:
(a) the selection of the temperature interval to be tested and, within that, the decision over the choice of the number and widths of the isostrips;
(b) determining the temperature at specified points of the surface under test (e.g. the centre point of the cross hairs);
(c) comparison between temperature distributions along the horizontal and vertical lines;
(d) determining the temperature distribution and mean temperature in smaller specified areas of the surface tested;
(e) statistical methods for the description of temperature distribution (e.g. histographic processing, and distribution curve of the histogram) and image filtering.

Thermographic evidence of previous radiation exposure can also be obtained in the latent phase of the pathological process (2). Unfortunately, the dose estimation cannot be performed immediately from the thermal map (thermogram). Recently, however, it is considered to be of value to demonstrate the dose range in which the thermographic signal, i.e. the change in the local temperature, indicates the radiation injury or burn. Accordingly, a series of measurements were initiated on patients submitted to ionizing radiation after surgical mastectomy. The evaluation of thermograms was made by computerized analysis transforming the altered temperature distribution to histograms (5, 6). By this more sensitive approach to analysis it was found that temperature alterations following even a dose 2.5 Gy from accelerated electron irradiation after the first treatment session could be detected and followed during the whole treatment. In a case report, the present authors also published a successful demonstration of temperature increase following an accidental 1-2 Gy irradiation of a hand (9).

Following the post-operative radiation treatment over a period of 3 weeks, three phases of effect were observed. The following characteristics of the thermal reactions were identified : in the case of the thermal approach to the quantitative measurement of radiodermatitis of ionizing irradiation, the thermal skin reactions at the beginning affected by the thermal equilibrium of two main factors, namely biological phenomena of irradiation effects and thermal regulation, i.e. injury and tissue regeneration.

The dynamics of the thermal reactions in the first week can be seen in figure 3. During the first week the patient was irradiated on consecutive days, four times, with 2.5 Gy each session. It is obvious that, after the first treatment session, i.e. 2.5 Gy, the temperature has been considerably increased (Fig. 10). The value of median temperature changed approxymately 32.5 to 34.5 °C .The shape of the distribution curve was not significantly changed.

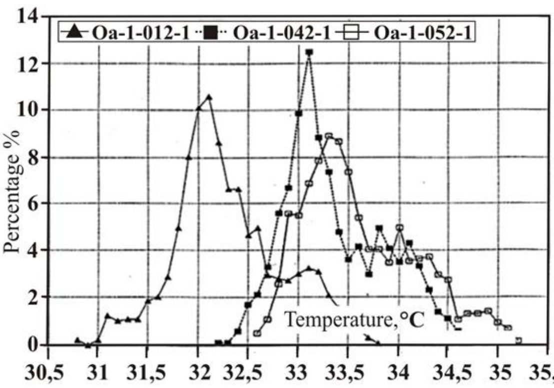

Fig. 10 - Series of histograms of the temperature values on the beta-irradiated areas at the 1st (No. 012), 4th (No. 042) and 7th (No. 052) day during radiation treatment (first week).

Accepting that the increased temperature is a normal tissue reaction to radiation-induced skin reaction, it can be seen that at the end of the first session the skin temperature increased (Fig. 10) in contrast with the second and third sessions (weekends) when it was decreased (Figs 11 and 12). This may indicate that the regulatory functions of the skin have been relaxed. On further irradiation, the radiation reaction were not additive; just a decrease of the average temperature was observed especially when there was a break of two days in the treatment protocol. Accordingly, the increases in radiation doses do not increase the tissue reactions but, in contrast, induce a modulation.

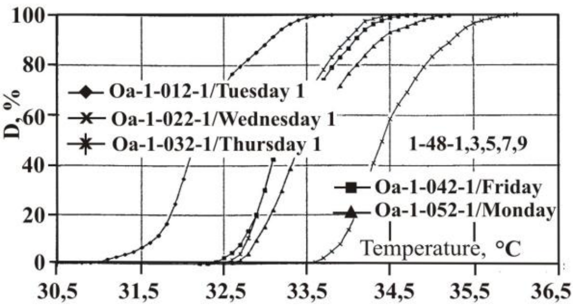

Fig. 11 - Series of distributions of the temperature histograms of β-irradiated areas in the first week.

Finally there is an equilibrium of skin reaction and thermal regulation's fluctuation. Lacking reliable dosimetry, the radiotherapist must consider the nature and severity of signs and symptoms, the protracted expression of the injury, and the timing and differential expression of injury in various tissues, when deciding treatment options and prognosis.

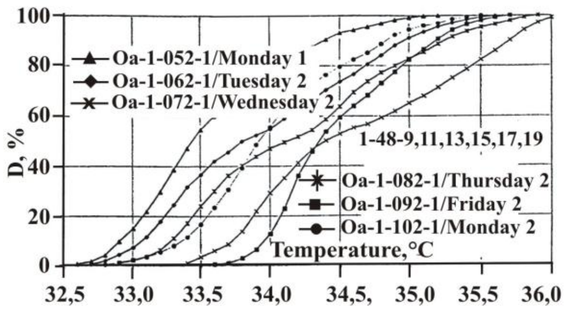

Fig. 12 - Series of distributions of the temperature histograms of β-irradiated areas in the second week.

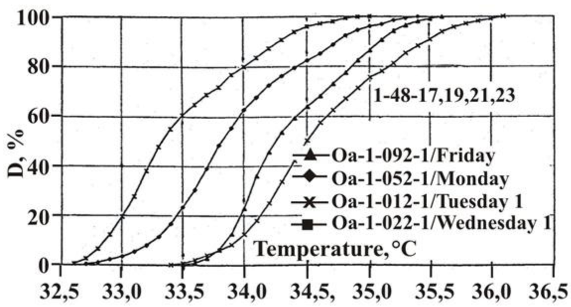

Fig. 13 - Series of distributions of the temperature histograms of β-irradiated areas in the third week.

In summary, the measurements from the thermal image proved to be useful tools in both the

prognosis of local radiation injuries in a wide dose range. A definitive non-invasive method to determine the extent and magnitude of a local or partial body radiation injury was found.
In addition, numerous techniques can be utilized to evaluate circulation in an affected area, to determine the volume, depth and area of tissue affected. Other medical imaging techniques include angiography, radionuclide imaging and non-invasive technique such as impedance plethysmography, magnetic resonance imaging and ultrasound. Techniques capable of evaluating superficial blood flow and tissue perfusion have clinical value for the physician, who must counsel the patient and make critical decisions regarding medical or surgical treatment.

7. CONCLUSIONS

The details of observed results are indicated in the legends of the figures. Diagrams are given describing the temperature variation effects resulting from the beta-irradiation in function of the time of treatment, as well as versus cumulative absorbed beta-dose.The results presented give evidence for the efficient use of infrared technique in diagnosis and follow-up of local beta-irradiation. Upon the former and present experience we suggest that infrared thermogrammetry can be used in detection of the extent of beta-irradiation even at doses which do not cause clinically significant signs and symptoms.

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