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BIOSTIMULATING LASER TREATMENT OF CHRONIC RHINITIS IN CHILDREN – MONITORING BY THERMAL IMAGING

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Chronic inflammation of the parallel nasal sinus is defined as a persistent bacterial process in the nose and sinus mucuus that continues for at least 12 weeks despite appropriate treatment.

Thermographic examination of the sinus area has become a recognized diagnostic method and thermographic images of children presenting with sinusitis reveal warmer thermal images in the maxillar projection of the sinus and frequently warmer orbits. Acute rhinitis produces increased nasal temperature only, while the allergic version is visible in thermography as an diffuse image of increased temperature with blurred edges.

The control group consisted of 20 children presenting with chronic and intensified rhinitis and treated initially with an antibiotic and later exposed to a biostimulating laser or with a long course of antibiotic therapy.

The reference group included 15 children undergoing a long term antibiotic treatment.

The thermographic images in both groups were comparable at the outset and typical of rhinitis.

At the end of the course of therapy the children were examined again: 10 laser therapy sessions or 14 days of antibiotic administration. Thermographic images became normalised in 16 out of 20 patients, and in the prolonged antibiotic therapy patients in 12 out of 15 cases. Subjective improvement – patent nose and headache subsidence was found in 19 out of 20 laser therapy patients as early as the fifth session, as compared to 10 out of 15 after 10 days of pharmacological treatment. In one case the thermographic image of the sinus indicated persistent inflammation and the patient required another antibiotic treatment.

Biostimulating laser treatment appears to be an effective alternative to long term antibiotic chronic rhinitis therapy in children.

Thermography can be used to monitor the effects of both pharmacological treatment and biostimulating laser therapy.

APPLICATION OF AN INFRARED METHOD OF APPLYING BIOFIX IMPLANTS FOR INTERNAL FIXATION OF INTRA-ARTICULAR FRACTURES AND FRACTURES OF TIBIAL EPIPHYSIS

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Over a period between 1998 to 2000, the Department of Pediatric Surgery of the Pediatric and Rehabilitation Center in Chorzów and the Trauma and Orthopedic Surgery Ward at the No 8 City Hospital in Katowice, applied BIOFIX screws and pins for the treatment of intra-articular fractures and fractures of tibial epiphysis with 6 patients. After completing the treatment the patients underwent an examination using an infrared camera. The results obtained proved the effectiveness of surgery using the BIOFIX method and wide potential of the infrared imaging examination for estimating the effects of surgical treatment.

REPRESENTATION OF PHYSIOLOGICAL AND PATHOLOGICAL CONDITIONS OF THE ORAL CAVITY MUCOUS MEMBRANE USING INFRARED IMAGING.

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The mucous membranes of the oral cavity performs many important functions. It creates a defence - protective barrier, it is responsible for taste and

touch, and has particularly effective capabilities of absorption and secretion. One can differentiate three zones of oral cavity mucous membrane, which differ from each other by means of thermal images according to their physiological condition. In pathological states thermal changes for particular disease changes (earlier compared to other clinical symptoms) were observed.

The thermal imaging camera is an instrument, which can provide precise temperature distribution on the surface of particular elements of the mucous membrane. The aim of this investigation is to establish a diagnostic methodology of early disease changes in the mucous membrane: its position in the oral cavity and its blood-supply.

There are three zones of oral cavity mucous membrane: chewing, cushion and a special. The three zones and particular structures within them (marginal gingival, proper gingival and moving mucous membrane of alveolar process) show different thermal images, which can be examined by infrared image analysis.

For a representative group of patients (30 persons) we defined the normal thermal image of particular zones of mucous membranes, and compared them to thermal images of mucous membrane, which demonstrated recognized disease changes. The results of this investigation can be used to formulate an assumption that it is possible to create a diagnostic method for the early detection of pathological changes in mucous membranes based on thermographic image analysis.

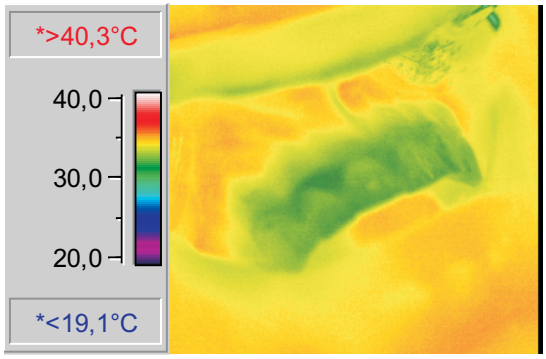

Fig 1. Normal thermal image of mucous membrane.

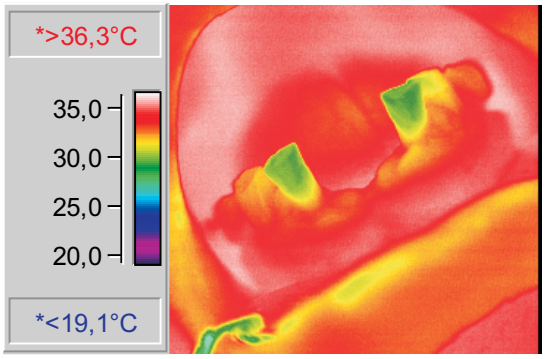

Fig. 2. Inflammation of marginal gingival (temperature increase inside pathological area can be seen).

INFRARED IMAGING FOR THE MEASUREMENT OF POST-MORTEM TEMPERATURE DECREASE OF THE HUMAN CORPSE

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The aim of this study was to apply thermography as a non-contact method for the determination of the time of death.

Changes in temperature of 20 undressed corpses (10 female and 10 male) were recorded using a Therma Cam infrared camera (Flir System, Sweden) in the mid-epigastrium region every hour for a period of 24 hours after death. Measurements were performed at a room temperature of 20 ^{o}C and constant humidity. Reference measurements were performed with a laboratory thermometer located in the rectum.

Infra red thermography was found to be free from the errors associated with established methods, and therefore appears to be a valuable alternative for recording cadaveric temperature.

THERMOGRAPHIC ASSESSMENT OF TEMPERATURE RISE ON THE ROOT SURFACE OF TEETH DURING THERMAFIL RETREATMENT USING SYSTEM B.

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The aim of this in vitro study was to evaluate the temperature rise on the outer root surface of teeth during reatreatment of Thermafil obturated canals using a technique based on the System B Heat Source. Ten extracted premolars were filled with size 40 plastic carrier Thermafil obturators and AH Plus root canal sealer. After three days, the Thermafil obturators were retrieved using a System B Heat-Source filled with a medium - fine plugger activated to a temperature of 225 °C. The plugger was placed buccally and then lingually to the plastic carrier to a depth of 10 to 15 mm for 8 s. This melted the gutta-percha and softened the plastic carrier (Wolcott, Himmel and Hicks, 1999). Temperature changes on the outer root surface were recorded by the infrared camera ThermaCam (Flir, Sweden). The temperature of certain regions of the mesial root surface was analyzed and the highest temperature values were recorded. Temperature changes were measured every 2 s for a period of 60 s. The average increase in temperature during retreatment was 40.4°C (after first plugger placement) and 54.1°C (after second plugger placement).The retreatment of Thermafil obturated canals using System B

technique causes a high rise in temperature in vitro that may injure the periodontium in vivo.

CORRELATION BETWEEN THE THICKNESS OF TOOTH ROOT AND TEMPERATURE RISE ON THE ROOT SURFACE DURING WARM LATERAL CONDENSATIOn.

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The aim of this in vitro study was to estimate the correlation between dentine thickness and temperature rise on the outer root surface during root canal filling by warm lateral condensation.

Fourteen extracted human incisors (7 upper – group 1 and 7 lower –group 2) were used in this study. The canals were prepared and gutta – percha cones were introduced into the canals. The Touch and Heat spreader was then placed to within 1 mm of the working length and heated four times for 2 –3 s with the control adjusted to a power setting of 3. The temperature changes on the mesial and labial root surface of teeth were recorded using ThermaCam (Flir, Sweden). The temperature increases were measured in the middle part of the root. The teeth were then transversally sectioned at the measurement points and the dentine – cementium thickness from inner canal wall to mesial and labial outer root surfaces were determinated.

In group 1 the temperature rise was 11.35 °C (the mesial root surface) and 9.95 °C (the labial root surface). In group 2 the temperature rise was 21.35 °C and 13.55 °C, respectively. The largest rise in recorded temperature was in teeth with a thinner dentine wall.

The present study shows that (a) warm lateral condensation of gutta – percha produced a relatively high temperature rise on the outer root surface; (b) heat transfer is dependent on the thickness of the root.

THERMOGRAPHIC DIAGNOSIS OF PERIODONATAL AREA IN CHILDREN AND ADOLESCENTS

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Reliable thermographic measurements have to be performed taking into account different factors affecting the actual temperature at a specific site. Thus local temperature depends on heat transportation by the organism's fluids mainly saliva and blood, degree of metabolism and on some mechanical effects. These may be from anaemia of the frenulum of the upper or lower lip as a result of application of the standard lip expander, and poorer circulation in the mucous membrane at the site of interest. Moreover, processes related to teeth eruption both in the pre-eruption and post-eruption phase may be manifested in the thermogram. Such processes can take place over a range of many years. The other factors that have to be taken into account include the pathological changes of pulp (inflammation, necrosis, gangrene) and the presence of teeth with filled radicular channels, hence care must be taken in choosing the site to be studied.

This report presents the results of a thermographic study of gingiva in the vicinity of central incisors. All the incisors and canine teeth were live, healthy with roots development completed. The measurements were performed in such a manner that the pressure of the frenulum did not cause anaemia at the site examined. In all subjects the standard lip expander of the same size was applied. The children with incorrect attachment of the frenulum of the upper lip were excluded from the group of subjects studied.

The study was performed in a room adapted for thermographic examinations with the use of a camera AGA Thermovision System 680 in a group of 18 healthy subjects (mean age 17,0 years) and a group of 32 subjects suffering from diabetes mellitus (mean age 16,5 years) representing both sexes .

Thermographic measurements were carried out a few times: prior to cooling with cool water and at 1, 2, 3 and 4 minutes after the cooling. The clinical assessment of the oral cavity health status was performed on the basis of the index of bleeding from the gingival crevice, SBI, according to Mühlemann and Son, estimated from the inflammatory status of gingiva based on the swelling and reddening of gingiva and bleeding when probed.

The assessment of oral cavity hygiene was made on the basis of the plaque index Pl I, according to Silness and Löe, being a measure of the plaque in the periodontal area.

For interpretation we have taken the weighted mean temperature as well as the maximum and the minimum temperatures at a given site. The data were subjected to statistical analysis by non-parametric tests of Mann-Whitney and Wilcoxon in order to compare the results for the left and right hand side in the group of healthy and diabetic children.

Preliminary analysis has confirmed the symmetry of the temperature distribution and mean higher temperatures of the periodontal region in children with long-term (on average for 7,5 years) IDDM.

Results of the statistical analysis of the SBI index revealed significant differences between healthy and diabetic children. Moreover, the subjects with IDDM revealed easier bleeding from gingival pocket when probed.

Analysis of Pl I index values has shown a better hygienic status of oral cavity in the group of healthy subjects.

The results obtained indicate the suitability of thermographic examination for assessment of the status of periodontal tissues.

THERMAL IMAGING AS A SCREENING METHOD FOR MILITARY PILOTS' LOWER EXTREMITIES PERFUSION DISTURBANCES

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Real time flight exposes pilots on highly changeable environmental factors, often with synergistic effects, that can increase development of disturbances to perfusion of the lower extremities.

Among pathogenic environmental factors are: acceleration, vibration, mental stress, altitude hypoxia, noise, and thermal discomfort. Despite many study reports the pathological changes determined by the impact of those factors is not clear. For this reason difficulties arise in medical certification of the cause and effect relationship in military duties. The problem is centred on the cardiovascular system and peripheral vascular changes. The cardiovascular system is one system to be most rapidly affected by environmental factors. Its physiological activity is directly modified by acceleration (depending of the force vector, magnitude, onset rate, and time), vibration (depending on frequency, amplitude, and energetic effects), altitude hypoxia and mental stress. Because of the small amount of time spent on board an aircraft, occupational exposure of pilots on those factors is diminutive, but they can not be totally excluded from the cause of perfusion disturbances. Further observations in this area are needed. For the prophylaxis of vascular diseases an important part lies in noninvasive diagnostic systems, that can provide early determination of pathological changes and early treatment.

This study was designed to asses how far the flying hours affect a manifestation of disturbances to perfusion in the lower extremities. 120 pilots in two subgroups were subjected to examination (flying hours over 1500, and below 1500). Testing was performed in the morning, in a steady, comparable environmental conditions (temperature, humidity, air movement) according to contemporary research standards. All individuals were tested with Doppler ultrasonography, thermal imaging imaging, and ankle-brachial index. An AGEMA Thermovision 900 system equipped with Short Wave scanner with 20° lens, adapted for medical imaging was used.

The results show that among military pilots examined (with varied duration of flying hours) there were no changes, shown by perfusion disturbances of assessed region of lower extremities. Thermal imaging results were confirmed by Doppler ultrasonography and ankle-brachial index.

This research study confirmed, that thermal imaging as a noninvasive method (and available in PAFIAM) can be successfully adopted for pilots' screening test of lower extremities to ascertain the presence of perfusion disturbances.

QUALITATIVE AND QUANTITATIVE ANALYSIS OF THERMOGRAPHIC EXAMINATION, USING IMAGE THERMABASE SOFTWARE FOR MEDICAL APPLICATIONS.

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The aim of this new software program was to make qualitative and quantitative analysis of thermographic images. The use of mathematics enabled us to obtain objective results of the image analysis. In this project we have established the module architecture. Following the acceptance of the criteria used will lead to specific software requirements for medical applications.

The default file standard used is TIFF (Tagged Image File Format),as available from the ThermaCAM SC-1000. This is also the default file format selected for the software package Image ThermaBase. However, the program can work with many different file standards as like as:

- CSV – define area of temperature in points;
- BMP, JPG, GIF, EMF, WMF, DIB, TGA, TIFF – standard graphics file.

The Program can capture an image from another device when it is compatible with Video for Windows or Twain standard, for example: video camera, scanner. If we acquire an image from the IR scanner some picture parameters can be modified:

- Brightness and contrast;
- Zoom in and out;
- Rotation;
- Horizontal and vertical reflection;
- Reduction to monochrome picture;
- Negative of picture;
- Digital filtration (45 filters include Laplace'a, Sobela, Prewitta, edge detection and gradient);

Image ThermaBase is a multi document application MDI (Multiple Document Interface) and therefore the user can work with many images results at the same time.

Result of thermal examination can be display in one of 15 color's scale. One of that can by defines by the user. For every scale minimal and maximal value of temperature can by changed.

For every new examination regions of interest can be defined as section, ellipse, rectangle, and poly-

gon. The user can move, copy, resize, and mirror a selected region. The Program permits the change of thermal parameters for every region. Regions of interest can by saved as a file and used in the feature as a pattern. Patterns are defined areas for analysis. From a thermogram Image ThermaBase the program compute scoefficients on temperature [^{o}C], and on brightness for graphic files (fore example: rtg examinations).

The Default statistical coefficients are:

- Minimum of temperature (brightness);
- Maximum of temperature (brightness);
- Mean of temperature (brightness);
- Median of temperature (brightness);
- Difference maximum and minimum;
- Standard deviation;
- Variance;
- Number of points in selected region;
- Area of region (not for selection);
- Periphery or length of selection region;

The program can calculate for every region either a histogram, slice or 3D chart for selected regions, isotherm line / isovalue, gradient in area.

Some of the new functions are to compare two regions from different examinations. Then Image ThermaBase calculates:

- Minimum of value in regions;
- Mean of value in regions;
- Median of value in regions;
- Maximum of value in regions;
- Difference between maximum and minimum;
- Standard deviation;
- Variance;
- Percent of difference between regions on defined limit;
- Percent of area where temperature (brightness) is less, upper then defined limit;
- Percent of area where temperature (brightness) is the same on defined limit, and was changed in this limit;
- Difference area of regions where increase and decrease was computed;
- Number of points that value is used to compute coefficient;

When coefficients are computed program calculate difference of regions, histogram and difference of picture. All histograms are evaluated in graphical forms and in table. Image ThermaBase can compare pictures graphical files to. When pictures as compared applications computed:

- Mean square error;
- Image fidelity;
- Maximum difference (peak absolute error - PAE);
- Correlation quality;
- Normalized cross – correlation;
- Structural content;
- Mean of difference;
- Peak signal to noise ratio;
- Minkowski norm (L_p);
- Signal to noise ratio;
- Normalized mean square error;
- Normalized absolute error;
- Peak mean square error;
- Laplacian mean square error;

Additionally user can generate sum, difference and product of picture.

The program can export results to Microsoft Word or other Windows application. The user can select those data to be exported to another programme.

Image ThermaBase can by integrated with thermal images and a medical database.

Conclusions

1.The program can objectively compare results of different thermographic examinations.

2.Image ThermaBase can compare both thermal and standard graphic pictures.

3.A high number of functions, user-friendly interface is included.

COMPARISON OF DIAGNOSTIC VALUES OF THERMOGRAPHY AND DOPPLER ULTRASONOGRAPHY IN RAYNAUD‘S SYNDROME IN CHILDREN

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The aim of this study was to compare diagnostic values of two methods - doppler ultrasonography and thermography and to apply them to assess the intensity of vasomotor disorders at the palm and monitor their treatment. The study included 30 children aged 11-18 years (19 girls and 11 boys) who all demonstrated the clinical symptoms of Raynaud‘s syndrome. Ten healthy children, who were aged matched, served as the control group. From the group of 30 children 18 were diagnosed with primary Raynaud‘s syndrome, whereas the remaining 12 developed secondary Raynaud‘s syndrome that

was accompanied by systemic connective tissue diseases. A similar protocol for cooling the palm was applied to both doppler ultrasonography and thermography.

A Toshiba corre-Vision Ultrasound system with a 7,5 MHZ probe was applied to investigate the radial artery flow over the wrist joint at room temperature. Thermographic investigation was performed by means of an AMBER IR camera providing a temperature resolution up to 0,02 Kelvin. The initial doppler ultrasonography of palm vascular flow was performed in children at room temperature, afterwards their palms were cooled at a temperature of 8-10°C within 4-5 minutes and immediately after the second doppler ultrasonography investigation was used to detect the change in blood flow quality. Thermography was performed three times - before cooling, directly after cooling and after 4 minutes. The results of Raynaud's syndrome patients were compared with healthy children according to the clinical outcome. Blood flow assessed by doppler ultrasonography presented only slight agreement with clinical symptoms. Preliminary investigations, and those after cooling were not of univocal importance. They were not only characteristic for Raynaud's syndrome, and proved to be difficult to interpret.

In the majority of cases the results of thermography investigation corresponded with the clinical course of the disease. The initial palm temperature of children with Raynaud's syndrome was lower than in control group (mean temp. $26,9^0$C versus $29,3^0$C). Directly after cooling the palm temperature fell by 1.8^0C, after 4 minutes it was increased approximately 1.5^0C in healthy children. Raynaud's syndrome patients did not reach these values (1.3^0C). The difference between these temperatures was not statistically significant. An attempt was undertaken to find if there were differences between primary and secondary Raynaud's syndrome patients, however blood flow did not differ significantly. The results of our study suggest that thermography is a suitable technique to monitor the severity of blood vessel changes and the efficacy of treatment in cases of primary and secondary Raynaud's syndrome in children.

APPLICATION OF THERMAL IMAGING FOR DIAGNOSIS AND FOLLOW UP OF CHILDREN WITH ORTHOPAEDIC DISEASES.

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In this paper some applications of thermography in pediatric orthopaedics are presented. Thermal images were compared with commonly used diagnostic methods such as radiological images, scintigraphy and computed tomography. Images of patients with Perthes disease, tumours, patients during limb elongation with Ilizarov instrumentation, and others were investigated. We have evaluated the thermal images in both the diagnosis and follow up in patients with Perthes disease.

All thermographic examinations were performed according to the European Association of Thermology standards.

PROVOCATION TESTS IN THERMAL IMAGING

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Infrared thermal imaging of the human body skin surface is normally carried out after a standard period of acclimatisation in a temperature-controlled room. A number of normal temperature patterns have been identified. Clinical abnormalities in temperature can be identified. Once the normal pattern is established. Dynamic reactions to provocation tests can be useful when there is a possibility of loss of thermal symmetry between the two sides of the body. The effects of some work related injuries on skin temperature may also be made more obvious following such tests.

= In general, provocation or stress testing the skin can be made by using either *Chemical, thermal or mechanica challenges.*

1.Chemical and pharmacological skin tests are used in dermatology.[1] These may be applied allergens, or inflammatory mediators such as prostaglandins, 5HT etc. Nicotinic acid compounds in sufficient dose are known to provide local and transient areas of inflammation on the skin under normal conditions. In certain circumstances, this reaction may be inhibited or enhanced, depending on local blood perfusion to the skin and the status of the sympathetic nervous system.

= 2.*Thermal* tests have been used primarily to quantify the finger and toe temperatures in Raynaud's Phenomenon.[2] Immersion of the hands in a water bath at 20^0C or colder for a fixed period e.g.1 minute, provides a useful clinical test of recovery which is related to the local perfusion and the sympathetic response. Normal subjects may produce reactive hyperaemia in the fingers, or should recover baseline temperatures quite quickly (<10 mins) A vasospastic reaction is marked by delayed recovery in one or more fingers. Exposure to Ultraviolet radiation may also be used to generate local inflammation, and has been used to test solar barrier creams on the skin in-vivo.[3]

3.*Mechanical* tests may be based on muscular work, by performing controlled exercises and observing the muscular heat so generated. This may be absent in some cases of pain syndrome or where permanent damage to the nervous or vascular system has occurred. In vibration white finger VWF, which is

work related, cold fingers and hands may occur as a result of local damage to the peripheral micro-vascular and nervous systems. Controlled contact with a suitable vibrating surface is one means of provoking a reaction in these patients. Rapid re-warming of the fingers is normal, but delayed localised recovery of skin temperature can be found in fingers affected by VWF.

Examples of the above techniques demonstrate that thermal imaging has a valuable role in assessing the response to provocation tests on the skin. Under standard conditions the tests can be quantitative, thus providing the means for clinical trials of pharmaceutical compounds, and evoking abnormal responses in certain injuries which affect the vascular and local sympathetic nervous systems.

THE HISTORICAL DEVELOPMENT OF THERMAL IMAGING IN MEDICINE

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The association between disease and human body temperature is as old as medicine itself. However it was not until Gallileo Gallilei developed his simple thermoscope that attempts to measure temperature had succeeded. It was some years later that closed thermometers and calibrated scales became available. Carl Wunderlich made the greatest progress by his development of the clinical thermometer and systematically recorded the progression of temperature in a large number of sick patients in 1871.

The story of infra red radiation began in 1800, when Sir William Herschel, the astronomer in England, detected heating rays beyond the visible red of the spectrum. His son John Herschel, after his death in 1840 made the first thermal image from sunlight using the evaporograph technique He used the term thermogram to describe the image, which is in common use today.

Earl imaging systems were developed during the 1940's and became available for industry and medicine first in 1959. The Pyroscan, and 1942 instrument was first used in Bath in 1959 and was able to show the increased heat over arthritic joints. The picture quality improved with the Mark 2 instrument, although each image could take 3-4 minutes to acquire, and were almost impossible to quantify.

During the 1960' and 70's a new generation of thermal imaging systems were developed in Europe, the U.S. and Japan. A big advance was made when oscilloscope displays were introduced and electronic isotherm could be added to the picture. By multiple exposure colour photography, the first colour thermograms were produced. Computers arrived in the mid to late 70's with the advantage of image analysis, colour diplays and importantly data and image storage. This marked the beginning of quantitative thermography.

Modern systems now use focal plane array detectors which can give high speed with high resolution for the first time.

Image quality has dramatically improved, and the techniques for employing thermal imaging in medicine can take advantage of the explosion in image processing. Providing that the right ambient conditions are used, and standardized techniques are adopted, thermal imaging can be expected to grow in clinical medicine.

THE SPORTI PROJECT FOR NORMAL THERMOGRAMS

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A new study to construct a database of standardized thermograms from normal subjects in progress at Glamorgan university. The name stands for Standardised Protocol for On-line Reference Thermal Images. A series of standardized images from 25 areas of the human body are being collected. A new approach to creating standard regions of interest based on anatomical markers is employed. A european health questionnaire is used for each volunteer to establish a primary screening which includes absence of pain or injury. This study has so far shown how variable traditional ideas on locating a region of interest on a thermogram can be, and that precise definition both of the field of view for image capture, and the selection of a standard shape for each ROI can greatly improve reproducibility.