XVII IMEKO World Congress
Metrology in the 3rd Millennium
June 22–27, 2003, Dubrovnik, Croatia

INFRARED THERMOGRAPHY AS A NON INVASIVE APPLICATION FOR MEDICAL DIAGNOSTIC

Walter Wild[1], Sebastian R. Schütte[1], Hans W. Pau[2], Burkhard Kramp[2], Tino Just[2]

University Rostock, [1]Institute for Measurement and Control Techniques, [2]ENT-Department, Rostock, Germany

Abstract – From 4 examples from the human medicine it is described how the application of IR-thermography can be applied as a non invasive measuring method advantageously for the diagnosis and therapy as well as for the installation of artificial cochlea-implants, screw connection of broken bones, observation of tissue violations by warning shot weapons and the recognition of vessel illnesses of legs and feet.

Keywords: medical application; IR-imaging; non invasive

1. INTRODUCTION

During the last years the IR-thermography has managed to conquer a strong place throughout different medical applications [1]. A lot of are diseases accompanied by temperature changes which can be registered comfortably and by an IR camera. As a non invasive procedure this provides the physician besides other established diagnostic methods with additional information prior, after and during surgeries. Without exaggeration it can be stated that the IR-thermography is used from “head to toe”.

Postoperative this method is very well suitable for pursuing wound -healing. The implantation of a cochlea implant into the head represents a strong interference into the scalp. Such new implants serve the removal of innate or acquired deafness. The instrumentation investigations have the purpose to determine changes of blood circulation conditions in these areas of the head, respectively to diagnose disturbances of the temperature distribution in relation to the starting situation after the implantation. Disturbing thereby is the new hair vegetation reconstituting already after few days, which dams an infrared mission of the skin surface.

Frequently arising accidents are injuries in the range of head and face: Here Thermography is tested as an operation-accompanying measuring method with face fractures. Since reorientation of broken face bones can only be succeeded by screws and metal tape, boring of bones is inevitable. Thereby developing warmth must be withdrawn from the process by application of proper cooling. Whether this succeeds, is determined with the IR camera.

Still more drastic head injuries denote damages caused by warning shot weapons. Not only damage to the ear caused by outsized acoustic noise (bang trauma, deafness) is to be considered, but also the heat wave generated by the explosion, including the gas and particle cloud ejected from the muzzle. This situation is simulated and observed with the IR-camera during lab tests at pig heads.

As further example for the employment of Thermography at the human body, the typical desease of civilization the circulatory disorder of blood flow at legs and feet is surveyed. With Thermography, temperature distributions and abnormalities therein can be made visible on large areas. In connection with ultrasonic investigations the physician can achieve his/her diagnosis fast and safely.

2. INVESTIGATIONS

2.1. Equipment

The IR-images are acquired with a FLIR/AGEMA Thermovision 550 camera in the waveband of 3,5 ... 5µm. For short distances the camera AGEMA 470 PRO equipped with intermediate ring 20 mm is applied in the waveband of 2 ... 5µm. Parallel, pictures of the same body regions are taken with a usual digital camera and integrated into the IR-report for better clarity during the process of interpretation. The evaluation of the thermographic images is conducted with the software ThermaCam Reporter 2000.

The determination of the emission coefficient ε of skin tissue is conducted within preliminary tests. During the reception of photographs it is tried to keep the ambient temperature at constant level. The patients are recruited from the normal patient´s occupancy of the clinic and from accident victims who are prepared shortly and on a long-term basis for a sugary as well as from patients with post-operative treatments. Healthy humans serve as calibration persons. In relation to every other form of temperature measurement the IR-thermography has the advantage that it is not cumbering the patient and can be repeated many times. A further advantage is it that both single frames and sequential video sequences can be recorded.

2.2. Investigations on patients

The newest, modern hearing aids are placed as a cochlea-implant below the scalp after boring through the rock bone of a deaf patient – particulary children. IR-imaging controls the process of healing and the body combatibility of the implants.

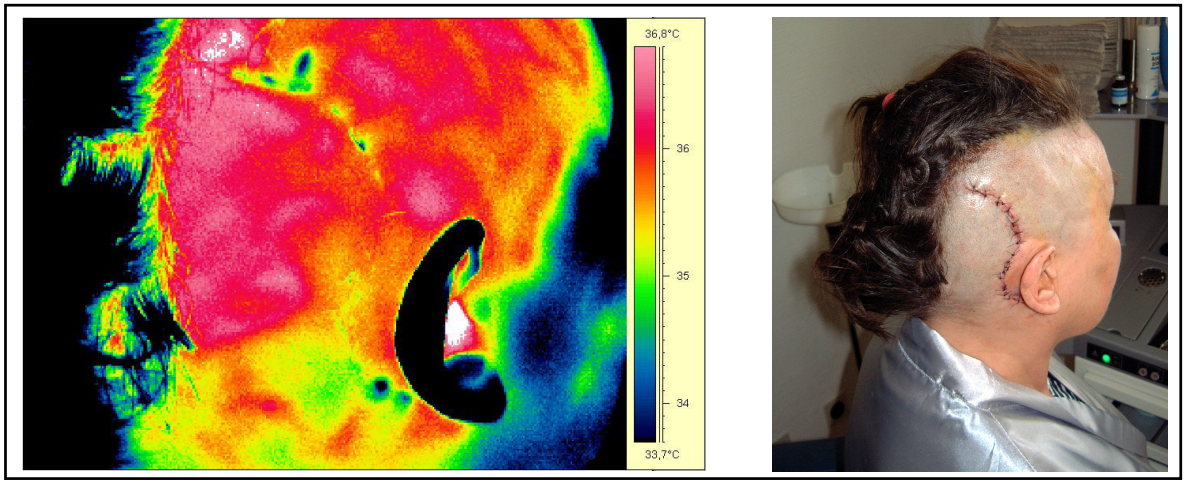

Fig. 1. Control of a patient`s wound healing one day after a Cochlea implantation surgery

Follow-up examinations in fixed distances are executed thermography-accompanying and afterwards the medical and physical results are compared with each other.

The implantation of an artificial Cochlea requires a difficult surgery. The scalp is to be cut open wide to lift up and the implant to be aligned and fastened to the bone. Already during the cut with the scalpel blood vessels, responsible for the supply of the outside head areas can devided. After the skin is sewn together again, Thermography recognizes whether an undersupply above the implant is developing. Figure 1 shows control of the wound healing of a female patient one day after the Cochlea implant operation.

Another application are broken face bones after accidents; for example a fractured zygomatic bone, is joined with special screws for coalescence. Before the screw fitting, preparatory holes must be bored into the bone. Due to the high heat development during the drilling process constant cooling of this area is essential. The temperature monitoring is taken over by the infrared camera. Temperature measurements with thermocouples have the disadvantage of only selective measurement and as a tangent procedure also lead away heat from the object itself, creating erroneous results.

The surgeon team is warned immediately, if the cooling does not take place precisely and inadmissible overheating arises (see fig. 2). Even when screwing the screws into the bored holes the local temperature exceeds the ambient temperature over up to 6 Kelvin [2].

Increasingly patients with head injuries caused by warning shot weapons come to the ENT-clinic. Besides the devastation of the eardrum and the harmful incorporation of explosion particles into the skin, the heat development leads to further, weighty damages of the tissue.

Shot wounds are particularly dangerous when the warning-shot gun is directly placed onto the skin in the head and neck range, since they lead to strong tissue destruction [3]. Whether the tissue destruction is caused only by the high gas pressure itself, or if thermal effects can also be taken into account, is to be clarified with Infrared Thermography.

Objects for investigation are fresh pig necks with head taken directly from the slaughterhouse. The investigations take place both at ambient temperature and after preliminary heating of the supplements on 30...34°C. The research programme comprises four usual warning shot weapons with 9 mm blank cartridges from 3 different manufacturers.

In order to recover the skin and tissue structures of the neck musculature clearly within the thermogram, surfaces and distances are formed from metal wires and precisely fixed on the supplement. Metal wiring and tissue have such a different emission coefficient that the wires stand out clearly in the thermogram.

Since the dimensions are known, the area-measured expansion of the rise in temperature can be computed very well after the shot. Synchronously to the shot a video sequence is recorded with the IR camera. Later, single frames are chosen from this recording. At a longer series of tests the heat entry is pursued and the destruction of tissue is analysed with a microscope.

In preliminary tests the temperature at the muzzle of the weapon is determined with shots in air. Temperatures around 100°C are beeing evidenced.

The fourth example in the application of the IR-thermography at the human body is the investigation of circulatory disorder of blood flow at legs and feet [4].

With the possibility of spread out temperature recognition, there is a high visibility of disturbances of the blood flow. Externally not yet visible, malfunctioning veins and varicose veins are reflected in the thermogram clearly. Locations with changes of blood flow witch cannot yet be detected by sonography represent themselves in the IR picture. Both measuring methods complement each other very well with the Thermography supplying a fast, integrated picture with overview character.

Toes and feet, badly supplied with blood often portray the beginning of a severe vessel illnes and can lead up to amputation.

This group of patients is an almost ideal object for thermographic measurement. In such pictures even the non professional recognizes the dramatics of the situation due to the colourization immediately.

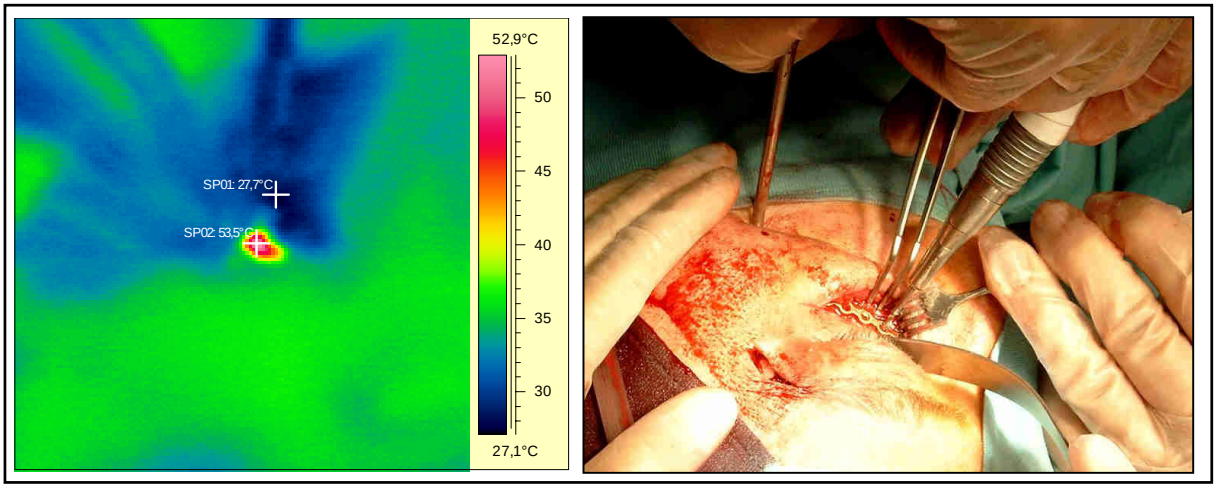

Fig. 2. Operative service to a fracture of the zygomatic bone

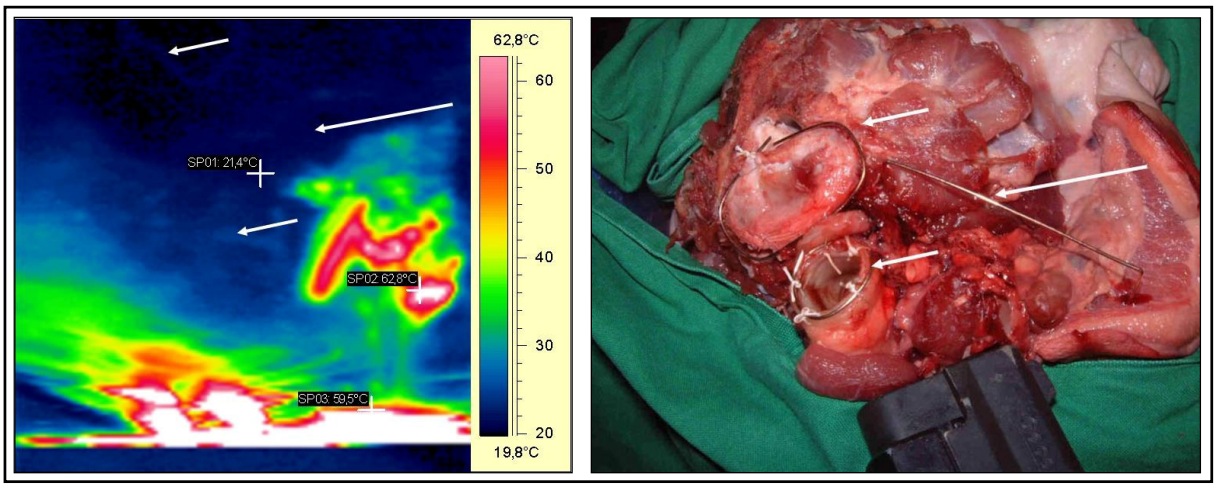

Fig. 3. Preparation of a pig neck with marking wires at skin placed warning shot before the shot (right) and after the shot as thermogram (left)

The venous system of the legs provides the return motion of the blood. It is collected by a large number of small vessels into two large leg veins, which then also unite and transport the blood to the heart. To overcome the force of gravity, the so called venous leg pump is used while contracting muscles and movements of the leg. Venous valves prevent flow backwards. If the cross sections of these vessels enlarge, the flaps do not close completely. This leads to chronic venous insufficiency and thus to the varicosis. With Sonography one is able to determine the direction of flow within the superficial veins, with Thermography the location and temperature. Additionally, also somewhat more deeply lying veins can be recognized with Thermography.

A third measuring method is Phlebography. Heavy contrast mediums have to be injected into the patients leg vessels and afterwoods the leg is beeing X-rayed, whereby very high dissolving pictures develop. Because of the high impact for the patient this method is used however only very rarely.

In addition arterial obclusive disease can very well be verified with IR-thermography. It expresses itself in cold feet, badly supplied with blood. Appropriate patients are usually diabetics or smokers.

2.3. Results

The call of IR-thermography in to the clinical cochlea implant study has had a positive effect on its results. The comparison of images between an operated and a non operated person shows immediately whether the implantation leads to circulatory problems of the skin or whether the existing vessel system remains unharmed.

Difficulties during IR reception occurs whenever a close hair vegetation is covering the skin again. The wound healing within the first days after the surgery can be pursued very well. In the thermogramm of figure 1 the scar and the module of the cochlea implant can be clearly recognized. The acquisition and/or reacquisition of speech recognition is now task of the paedagogues; the skin compatibility examination is task of the IR-thermography. All patients included in the study were able to leave the clinic without complications and also had no problems during aftercare.

The thermal observation of boring into bones lowers the risk of wrong application of the cooling and flushing. A current example arises from the thermogramm in Fig. 2. The rinsing solution has a temperature of 27,5°C and the opened skin areas of about 35°C.

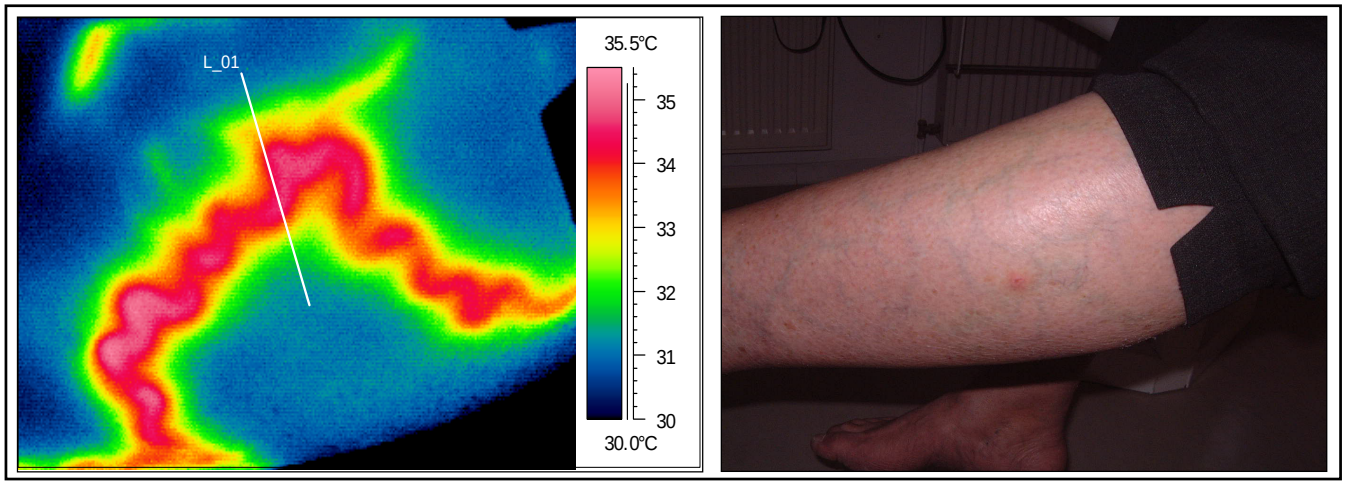

Fig. 4. Concise cramp vein infestation at the left shank of a patient

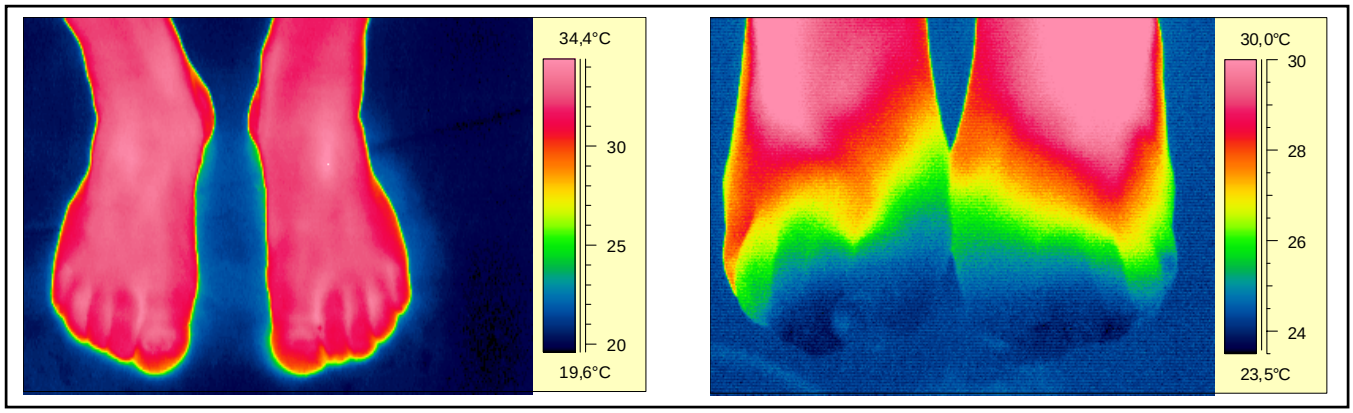

Fig. 5. Healthy feet (left) and ill feet (right) as thermogramm

Only for a short period of time the rinsing solution does not reach the point of contact at the diamant-drill and the temperature very quickly rises up to 50°C.

Within preliminary tests while boring at bone preparations with diamant-drills and without water cooling even over 100°C were measured [2]. This basic knowledge over the temperature development during the drilling process is very important for the surgeons. The unique conclusion is called: The coolant must meet the position and tip of the drill or mill accurately , no matter how it is applicated!

Only IR-thermography is able to aquire the variations in temperature fast enough. The only difficulty is, to have sufficient visual field for the camera during the conduct of operation.

The just described advantages of Thermography can also be transferred to the firing attempts. No other measuring procedure is able to record this brief heat effect.

Few milliseconds after the shot is fired it comes to a momentary rise in temperature. The withdrawing gas jet (300... 500 bar) pierces the skin and destroys the soft parts of the neck below. The heating decreases after few seconds. That means, that deeper lying tissue is not damaged by the warmth any more. Damaged portions of superficial tissue and marks resembling a tattoo caused by permeated burned and unburned gun powder remain. Thereby caused infection of the wound impairs the healing process.

Therefore, shot wounds at the neck with the warning shot gun put right onto the skin are highly lethal. However thermal damage is comparatively small, although the propellants develop a temperature from 2400°C to 3000°C while exploding. In the more deeply lying neck layers the temperature increases only insignificantly. Only the tissue layers very close to skin are drawn by thermal effects with momentary temperature rises over 60°C (Fig. 3).

Preliminary to a surgery of varicosis patients the physician provides himself with an overview of the run of the veins and their passage ability. In most cases he relies thereby on his visual impression and the results of sonographic examinations. With Thermography at his hand, he now has possibility of receiving improved statements on the degree of disease. The thermogramme dissolves individual vessels clearly, even if they are not visible to the human eye. A build up from small individual pictures – as with Sonography - is not applicable, because an entire leg section can be shown in one single picture (Fig. 4). With support through Thermography the physician can prepare the surgery better accomplish it more successful.

The infrared measuring technique supports the physician also at the treatment of further illnesses the bloodvessle system, like for example the arterial occlusive disease. Thermography recognizes clearly the areas badly supplied with blood, which become apparent by temperature differences of 8...10 K.

Concerned are especially the outer extremities like fingers and toes. A comparison of thermograms of healthy and ill patients results in additional
safety during interpretation of the results (Fig. 5).

3. CONCLUSIONS

The IR-thermography has become a welcome additional measuring method for the physician, being able top measure and pursue surface temperatures contact-free statically and dynamically.

The advantages of Thermography covering large surface areas with a colored representation makes it so attractive. With additional treatment of the pictures temperatures can be determined point for point and read off from any place of the thermogramm. Simultaneously temperature distributions can be plotted along a line, which can be placed arbitrary into the picture and temperature averages within specified areas (circles, squares, rectangles) can be indicated.

With the cooperation of physican and technical engineer Thermography has entered already many fields of human medicine and will open account of its strong advantages even more areas.

REFERENCES

[1] D. Balageas, G. Busse, C. M. Carlomagno, B. Wiecek, QIRT 1998/4: "Medical Infrared Thermography", *Proceedings of Eurotherm Seminar* no. 60; Lodz 1998

[2] H. W. Pau, J. Fichelmann, W. Wild, „Thermografische Studie zu Temperaturentwicklungen während chirurgischer Eingriffe", *Laringo-Rhino-Otologie* vol. 77, no. 12, pp.677-681, 1998

[3] M. A. Rothschild, D. M. Krause, „Schreckschusswaffen – eine unterschätzte Waffengattung", *Arch. Kriminol.* vol. 197, pp. 65-75, 1996

[4] W. Wild, S. R. Schütte, M. Grosse, „Thermal imaging in the field of diagnostics and treatment of varicosis and succeeding symptoms",
QIRT 2002, Book of Abstracts, pp. 136-137, Dubrovnik 2002

Author: Prof. Dr. Walter Wild, University of Rostock, Institute of measurement and control techniques,
Albert-Einstein-Str. 2, D-18051 Rostock, Germany
phone: 0049 / 381 / 498 3100; fax: 0049 / 381 / 498 3098
e-mail: walter.wild@mbst.uni-rostock.de

Remarks: We like to thank Mr. Dipl.-Ing. (FH) E. Langnau for his commitment during preparation of the IR-images