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THERMOGRAPHIC EVALUATION OF RESULTS OF SYNOVECTOMY IN RHEUMATOID KNEE JOINTS

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INTRODUCTION

Every object with a temperature above absolute zero radiates from its surface electromagnetic waves. These appear within the infra-red sector of the spectrum. This self-emitted energy can be collected optically and transformed into proportional electrical impulses. In turn these can be converted into visible light to form a picture, a so-called thermogram (*Lawson* 1957). A thermogram is thus a pictorial representation of the temperature contours of an observed surface. Its reproduction does not require any external illumination nor irradiation of the object which may be human or otherwise. It can therefore be made in complete darkness and does not depend on skin colour or pigmentation but relies to a certain degree on the temperature of the skin (*Barnes & Gershon-Cohen* 1963). This is in contrast to infra-red photography which depends upon the reflection of waves from the surface of the object which has to be irradiated with short wave length infra-red from an extraneous source (*Barnes* 1963).

The waves radiated by the human body by virtue of its temperature are from 3 to 20 microns and within these limits the human skin is essentially nonreflective and nontransparent. According to certain basic laws of physics it thus acts as a perfect emitter of infra-red energy (*Hardy* 1939).

For the last ten years these properties have been utilised in medicine. In 1956 Lawson demonstrated that certain cancers of the breast were associated with a rise in the overlying skin temperature. He produced heatpictures demonstrating graphically the temperatures he had noted

with a thermocouple. The new technique was called thermography. The pictorial registration of biologic, dynamic events has become greatly facilitated since by the introduction of accurate and easyhandled infra-red cameras.

In short, the working concept of a thermograph is that it attracts the emitted heat rays the vertical of which are transferred via a plane mirror and the horizontal by a rotating prism to a photoconductive detector of indium antimonide. The sensitivity of this is increased by cooling it with liquid nitrogen. The detector signal is then fed to a display unit where a television-like picture is obtained on a screen. This picture can be adjusted for contrast (temperature range) and brightness (temperature level) by controls on the display unit. It thus becomes possible to model out the pictorial registration of the emitted heat and temperature differences down to 0,2° C can be revealed (*Björk* 1967).

The practical value of thermography in clinical medicine appears to be dependent on conditions which give an increase in local tissue temperatures and inflammatory states seem to be ideal for this (*Brånemark* 1967). The rise of temperature of affected joints in rheumatoid arthritis provides a useful measure of the activity of the disease. With infra-red thermography it has proved possible to follow the progress of the disease and the influence drug therapy may have (*Boas* 1964, *Cosh & Ring* 1967, *Lloyd Williams* 1967). As yet no reports have dealt with the thermographic assessment of rheumatoid joints subjected to surgical treatment involving removal of synovial tissues.

The purpose of this study has been to evaluate the results of synovectomy in rheumatoid knee joints by employing thermography as an objective instrument of registration.

MATERIAL AND METHODS

Patients with rheumatoid arthritis fulfilling the requirements of the American Rheumatism Association were selected (*Ropes et al.* 1958). Only kneejoints were studied as these more easily lend themselves to other objective supplementary evaluation methods like intra-articular temperature measurements, radiology and pathomorphologic and biochemical investigations which by comparison facilitate and make the interpretation of thermograms more reliable. Patients with swollen periarticular tissues and articular exsudates were preferred for synovectomy. The radiologic appearance of the joint structures varied but did not limit the indications for synovectomy. No greater deformities were present. All joints were stable and all patients were mobile though with differing degree of activity prior to surgery.

In all, 25 patients representing 27 kneejoints were operated.

The synovectomy was in all cases performed through two parapatellar incisions. The synovium of the medial and lateral compartments and of the suprapatellar bursa was removed. The Hoffa fat pad was left intact. In cases with destroyed semilunar cartilages the remnants were excised. Synovial granulations around the cruciate ligaments were cut away. The synovium of the posterior region of the capsule was left. Destructions in the bone-cartilage zone were smoothed off and osteophytes chiselled away. Great care was taken to remove all pathologic tissue from the bone-cartilage zone. The fibrous capsule was sutured with silk and suction drainage was applied for approximately 24 hours. The operations were done under a tourniquet. Mobilisation was instituted immediately after operation and the patient was permitted to move freely around with weight-bearing as soon as there was relief in the postoperative pain.

Thermograms were made before operation and at regular intervals postoperatively as a rule after 6 weeks, 3 months (at which time the synovial tissue has regenerated, *Stevens & Whitefield* 1966, *Marmor* 1967, *Goldie* 1968), 6 months, one and two years In the earlier stages of this work a thermograph from FOA (Försvarets forsknings-anstalt) was used but later an AGA Thermovision which permits plotting of isotherms.

Simultaneously skin temperatures were recorded by directly applied thermocouples.

RESULTS

In all instances the same type of emission pattern was registered. The region corresponding to the synovial distribution showed prior to surgery an emissivity which was largely increased as compared to that of the surrounding tissues. As a rule the topography of the joint capsule could easily be outlined by the sharp border demarcating the area of increased heat emission. Within this region variations were seldom seen but it could occur that the area corresponding to the Hoffa fat pad stood out more intensely. This was especially noticed after synovectomy when the intensity in synovial emissivity was lowered.

Six weeks following synovectomy no changes were registered in the thermograms. This was believed to be due to a prolonged postoperative reaction possibly because of reactive hypervascularisation during the initial stages of synovial regeneration.

At three months a marked reduction in emissivity was registered in all cases but there was still considerable heat being emitted especially in the zones of incision which again was interpreted as hypervascularisation representing a normal constituent of wound healing.

At six months and one year—a considerable time after full regeneration of synovial tissue—the heat emissions fell within normal limits.

Two illustrative cases have been selected to demonstrate that which has been recorded all along this series.

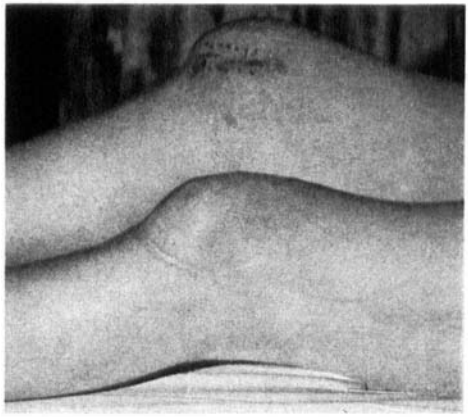


Figure 1. Knees of patient as case no. 1. After synovectomy. The upper knee is the right from the medial aspect, the lower the left from the lateral.

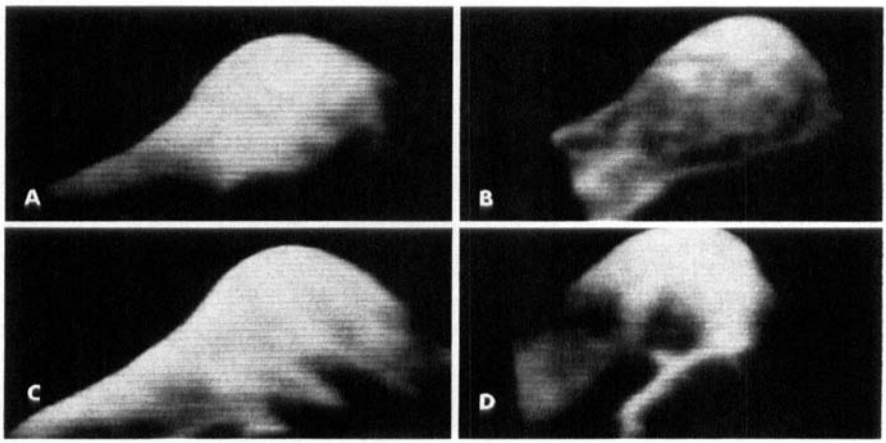


Figure 2 a. Thermogram preoperatively of outside of left knee. Even distribution of heat emission within limits of synovial lining of the joint.

b. Inside of left knee at same time as a). Increased emission is noticed within the joint but especially around the patellar region which is a common phenomenon.

c. Preoperative thermogram of inside right knee.

d. Outside of right knee at same time as c). The oblique streak of increased emission in the lower part of the field is from a subcutaneous vein.

Case 1

A 62-year-old male previously healthy but with rheumatoid arthritis since 1959. Admitted for articular soft tissue surgery in 1964. Most joints were involved but the patient suffered mostly from his knees with a certain preference for his left, which was operated with a near total synovectomy after admission. The patient's knees are seen in Figure 1, after synovectomy. There is a slight extension defect which is more marked in the right knee. The preoperative thermograms (Figures

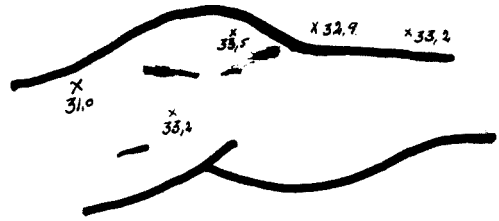
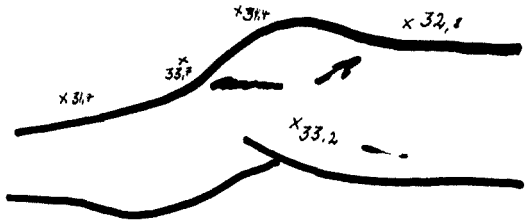
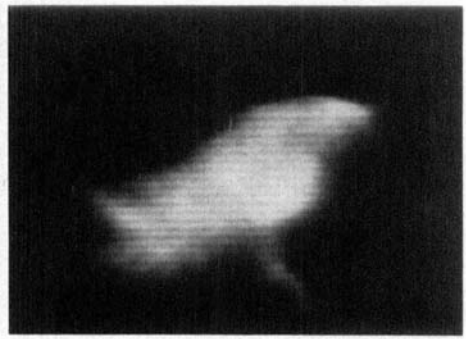


Figure 3 a. Result of direct measurement of skintemperature of left knee in case no. 1 at the same time as the preoperative thermogram was made. The figures indicate the temperatures in Centigrade.



b. Same as a) but right knee.

Figure 4. Thermogram of left knee in case no. 1 eight months after synovectomy. Heat emission above normal, but lower than preoperatively. Concentration of heat to Hoffa fat pad and patellar region which is a common finding.



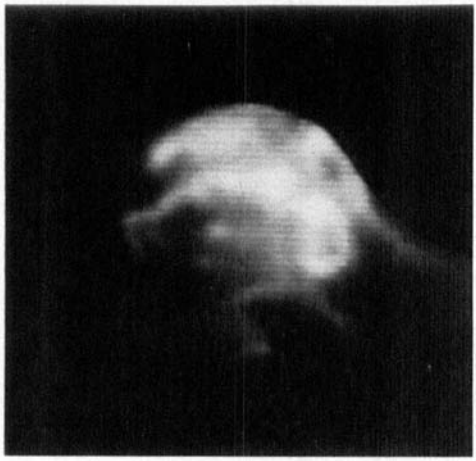


Figure 5. Thermogram of outside of right knee in case no. 1 five months after synovectomy. There is a marked decrease but serpentine emission pattern belongs to veins.

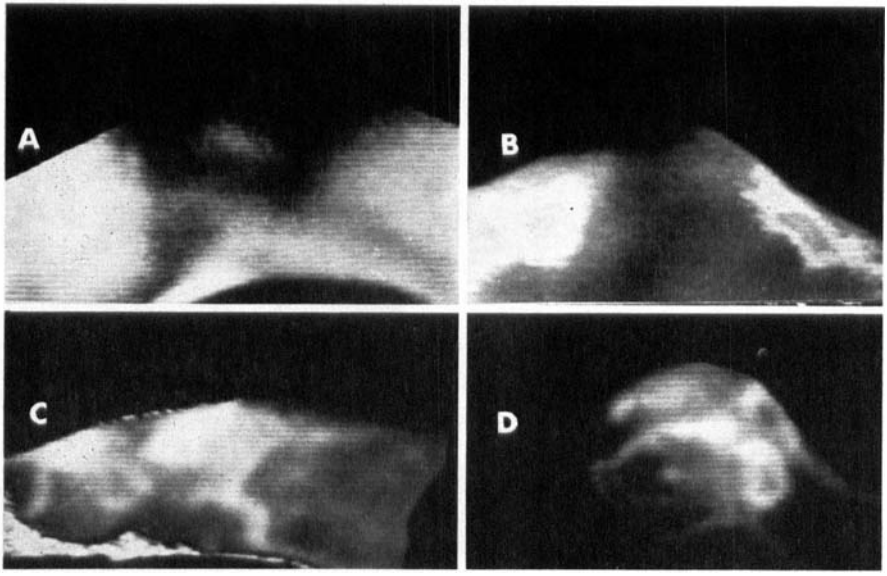


Figure 8. Thermogram of both knees prior to synovectomy in case no. 2. Increased pletely normal emission with modelling out of surrounding areas.

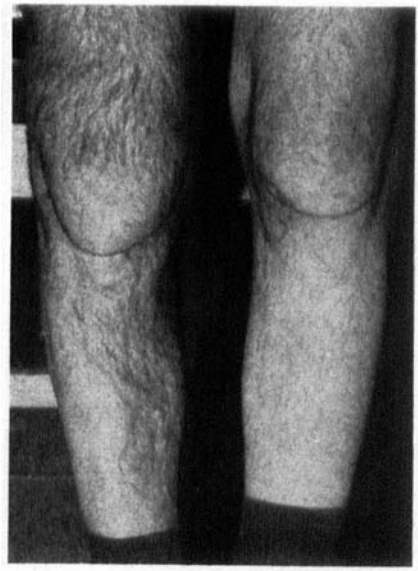
b. Inside of same as a). Here the modelling has been centred on the tibial tuberosity which normally is a hot spot.

c. Inside of right knee one year after synovectomy. There still remains some increased heat emission around the Hoffa fat pad which is regarded as normal. Oblique streaks of emission represent veins.

d. Outside of same as c). As compared to Figure 5 the decrease in emission is noticeable.

2 a, b, c, d) show intense heat emission well localised to the expansion of the synovial tissue. Strangely enough the emission is stronger from the right knee which clinically was better than the left. In order to discern how much heat emanated from subcutaneous tissues as compared to what the overlying skin might give off, direct skin temperature readings were made at the same time with the values as seen in Figures 3 a, b. These fall within normal estimates. The part played by the skin as a heat emitter was therefore regarded as nil. The patient was discharged after ten days fully weightbearing without other pain than postoperative discomfort. Subsequent thermograms showed a slow regress and at a new admission for synovectomy of the right knee eight months after the first surgical intervention in the left knee the thermogram of this appeared as is seen in Figure 4. There is still some heat emission but markedly decreased and now more localised to the patellar region and the Hoffa fat pad. The right knee was operated with a near total synovectomy and prior to this a thermogram displayed the same heat emission as seen in Figures 2 c and d. A thermogram of the right knee five months postoperatively is seen in Figure 5. There is still an increased emission as compared to surrounding tissues but decreased in comparison to the original thermo-

Figure 7. Knees of patient no. 2, one year after synovectomy.



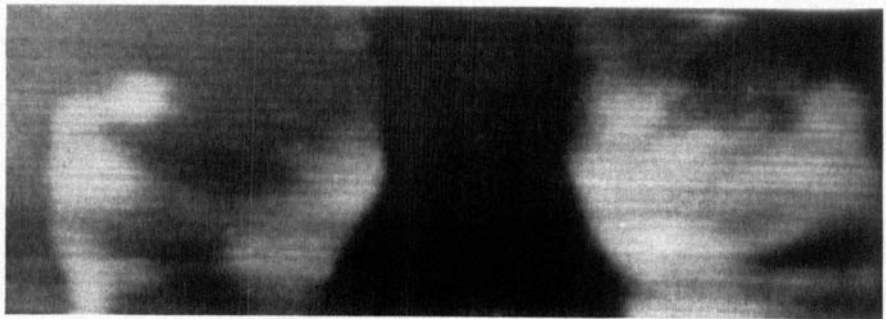


Figure 8. Thermogram of both knees prior to synovectomy in case no. 2. Increased emission especially around the medial aspects where as a rule the swollen knee is most bulgy and has the most affluent synovium.

gram (Figures 2 c and d). The left knee at 20 months postoperatively shows absolutely normal conditions (Figures 6 a and b) and the one year control of the right knee (Figures 6 c and d) shows a further decrease with almost normal emission. Clinically the patient has shown a steady improvement as regards his knee condition.

Case 2

A 47-year-old previously healthy male with rheumatoid arthritis since 1956. All joints involved but especially the knee joints. In January 1965 synovectomy was performed in the left knee and in March of the same year the right knee was proceeded with. Figure 7 shows the appearance of the operated knees one year after

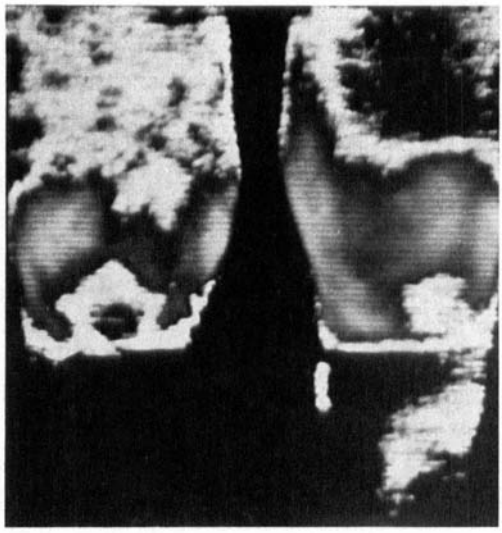


Figure 9. Thermogram of case no. 2 one year after synovectomy. There is now normal emission which can be visualised by the difficulty in scanning this area free from the emission of the surrounding tissues.

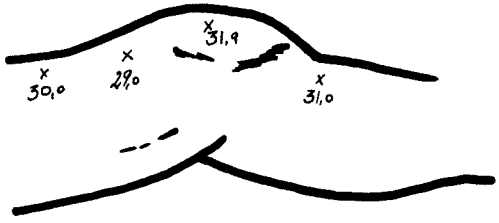


Figure 10. Direct skin temperature measurement in case no. 2 at time of first synovectomy. Temperatures in Centigrade.

the second operation and in Figures 8 and 9 the thermograms preoperatively and one year postoperatively are reproduced. The tissues around the joint now emit more heat than the joint itself. Skintemperature recordings at the time of the first synovectomy are seen in Figure 10 and prepresent normal values. The patient who has been wheelchair bound for more than two years now freely moves around.

COMMENT

In this investigation it has become evident that infra-red thermography is a useful supplementary tool in the recording of the therapeutic effect of synovectomy in rheumatoid arthritis. The evaluation by this method which is objective and non-touch—thus without extraneous interference which often accompanies many registration methods—is of value as other reliable and comparable parameters are difficult to obtain. Moreover it presents detailed information over a large area in contrast to that received by point sources. Another advantage is the sensitivity of

the registration device in its prompt depiction of biologic dynamic events as *e.g.* reaction of an inflammatory condition to anti-inflammatory drugs (*Cosh & Ring* 1967) or vascular response to vasoactive substances (*Brånemark* 1967).

The advantages thus combined with the use of this method are entirely dependent on the heat emitted from the surface of the scanned object. In this study it has been taken for granted that the emitted heat is secondary to the vascular state of the synovial tissues and the question arises if nearby structures like bone, muscles and overlying skin may add or subtract to the appearance of the final thermogram.

Body temperature as a rule is well controlled to about 37° C. The skin however, which normally is of a lower temperature than that of the body exhibits thermal fluctuations dependent on its environment. Extraneous heat or cold sources have been thought to cause changes in skintemperature *(Barnes* 1963). But normal human skin is a most suitable emittor in the long wave length infra-red and it is impossible to make it appear hotter by applying foreign substances. It should however, be pointed out that fat acts as a good insulator excepting those instances where there is rich vascularity as in the Hoffa fat pad. As a rule regions containing fatty areas do not appear in the thermogram and consequently are regarded as cold spots. Other factors which have a heat effect are thermal conduction from heat sources within the body, vascular activity within and below the skin surface, propagation of caloric energy in form of heat loss by respiration and metabolic tissue events. These may all influence the thermogram but they can be minimized by making the study with the subjects in an air conditioned room with a low temperature and after a period of adjustment to optimal thermal conditions. With such precautions the thermogram becomes a true thermal topogram of the surface of the body and the contrasts obtained arise largely from the heat conducted to the skin over the corporal regions registered.

This study has been performed taking all abovementioned precautions into consideration. The skin temperatures were measured and disclosed normal values. Therefore the thermograms of the rheumatoid kneejoints have been regarded as the final result of deep and superficial circulatory mechanisms and of tissue metabolism in the affected areas. The changes observed in the postoperative thermograms have been ascribed to the surgical removal of tissues, the site of these circulatory and metabolic disturbances.

SUMMARY

Synovectomy has been performed in 25 patients representing 27 knee joints. All patients had rheumatoid arthritis as classified by the American Rheumatism Association. An objective way of registering the postoperative course was found in the use of thermography, a pictorial scanning system of the heat which is emitted from the body surface.

Repeated postoperative thermograms showed that in all patients a decrease in heat emission followed synovectomy. This is interpreted as an amelioration of the inflammatory state of the joint. Clinically an improvement followed which paralleled the lessened intensity of heat emission.

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For further and more detailed information about thermography in clinical practice see: Thermography and Its Clinical Applications which is a monograph and registered as vol. 121, art. 1, Oct. 9, 1964 (304 p.) of the New York Academy of Sciences.