THE USE OF THERMOGRAPHY IN THE ASSESSMENT OF DEPTH OF BURN AND BLOOD SUPPLY OF FLAPS, WITH PRELIMINARY REPORTS ON ITS USE IN DUPUYTREN’S CONTRACTURE AND TREATMENT OF VARICOSE ULCERS

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Thermography is a non-contacting, completely passive and objective means of measuring the temperature and thus indirectly the blood flow of an area of skin. Every object warmer than absolute zero emits infrared radiation which may be measured with a thermographic camera. The camera scans the area vertically and horizontally by a revolving mirror system and the infrared radiation is focused on an indium antimonide detector cooled by liquid nitrogen. This in turn converts the irradiation into an electrical signal, which is amplified and displayed on a screen. Parts at the same temperature are known as isotherms and when adjacent isotherms are coloured differently by a series of seven filters a heat contour map in colour is obtained (Fig. 1). Recordings may be taken at any time and rapidly on Polaroid paper. (For full details see Chucker et al., 1971.)

Fig. 1. Thermogram of a girl in bikini briefs (does not have a bra on). Below is a temperature to colour scale covering 7°C. The white areas in the neck, for example, are 5°C warmer than the red areas of the breasts. Finer detail is possible closer to the patient. The symmetrical pattern of the body temperature is well shown.

Estimation of the depth of a burn. A preliminary report on the use of colour thermography in estimating burn depth has been published (Hackett, 1971). Many more cases have since been examined and it is now possible to review the results in 109 patients in whom 314 areas were studied. A typical case is shown in Figures 2 and 3.
Patients were examined by consultant plastic surgeons who were asked to assess the depth of the burned areas using the method they commonly employ. Most depended on visual examination and history but some used a pin-prick test as well. The patients were then examined thermographically.

Where feasible, the burned area was compared with a similar unburned site on the body; for example, one arm compared with another. If this was not feasible, a
chart of the expected temperature variations was used (Hackett). If the temperature drop was 2°C or more from the temperature of a corresponding site, or the expected temperature, a full-thickness burn was diagnosed. Between 2°C and 1°C was diagnosed as a deep dermal burn which would benefit from excision. Less than this was regarded as a partial-thickness burn which would heal spontaneously. An increase in temperature indicated a superficial burn.

The depth of burn was finally diagnosed by the length of time it took to heal spontaneously or by the histological examination of burned tissue excised. If the wound healed within 7 days it was regarded as a superficial burn; longer than this was a partial-thickness loss, and if grafting had to be carried out full-thickness loss was diagnosed.

The clinical assessments of the areas involved were incorrect in 74 while in 28 the surgeon said he didn't know. In other words, simple clinical examination failed in one-third of the cases. Thermographic diagnosis was correct in all but 34 instances (10 per cent), and all but 4 of these were deep burns which were assessed as partial-thickness loss.

Thermography is therefore considered to be a superior method of diagnosing the depth of a burn than simple clinical examination.

**Assessing the blood supply of flaps.** Of the 20 or so methods devised to assess circulation and viability in flaps, none is in routine use because none is simple to use. At the same time, the results of these investigations have all indicated that most flaps may be moved earlier than the empirical 3 weeks which is commonly adhered to. There is therefore still a need for a simple reliable test for flap viability, and thermography would seem to be the answer.

Flaps were examined on the 14th post-operative day and on alternate days thereafter.

The examination consisted first of a straight thermogram. The end of the flap was then occluded with a protected soft intestinal clamp until the patient experienced minimal discomfort. The clamp was left in position for 20 minutes and a thermogram taken each 5 minutes. In no instance was there any deleterious effect on the flap from the examination.

Of the 33 flaps examined there were 9 deltopectoral, 8 cross leg, 7 groin, 5 abdominal and 4 forehead flaps. Fifty-eight final pre-operative assessments were made because of multiple transfers and delay procedures. The results were:

- 39 flaps were divided at 3 weeks without any loss of tissue. All had a temperature drop of 2°C or less on occlusion;
- 4 flaps were divided at 16 days without loss of tissue. Each had a temperature drop of less than 2°C;
- 1 flap was divided successfully at 3 weeks with a temperature drop of 3°C on occlusion. Minimal tissue loss was noted;
- 5 flaps were divided at 3 weeks with a temperature drop of more than 3°C with a major loss of tissue;
- 4 flaps were delayed at 3 weeks because of a temperature drop of over 2°C on occlusion. They were moved successfully at 26 and 27 days when the temperature drop was less than 2°C.

One forehead rhinoplasty flap was examined at 3 weeks and a forecast made that if the flap was divided the nasal part would survive but the 4 cm of the flap adjacent to the nose would be lost when the flap was returned to the forehead. This was exactly what happened (Figs. 4-7). It was presumed that the flap which had looked precarious for the first 4 days following operation had picked up a blood supply from the nasal defect and was virtually a full-thickness free graft.
It is concluded from this study that, when a flap is occluded for 20 minutes and the temperature drop is $2\frac{1}{2}^\circ C$ or less, the flap is ready to move.

**Blood supply in Dupuytren's contracture.** Forty-six hands affected by Dupuytren's disease have been examined. All have shown temperature drops of more than $1^\circ C$ and up to $3^\circ C$ in the affected fingers compared with the other fingers (Fig. 8). Even a finger minimally affected showed these temperature changes. Difficulty was experienced with examination of fingers grossly distorted by the disease.

Fourteen children of patients with Dupuytren's disease have been examined varying in age from 12 to 40 years. In only one hand of the 28 examined was there any marked temperature variation. This was in a 24-year-old man where a ring finger was $1\frac{1}{2}^\circ C$ colder than the rest of the hand with no apparent cause.

This is obviously a long-term study but it is felt one worth persisting with.

While studying the vasculature of the hands, the effect on the circulation caused by cigarette and pipe smoking in non-smokers and regular smokers was checked. Non-smokers will dramatically drop the temperature in their hands and fingers by up to $2\frac{1}{2}^\circ C$ within a few minutes of inhaling from a cigarette, whereas regular smokers drop the temperature by only $1\frac{1}{2}^\circ C$. Pipe smoking has no effect on regular smokers and a loss of temperature of $\frac{1}{2}^\circ C$ in non-smokers. A similar effect is seen with cigars. This
suggests an alteration in vascular lability in cigarette smokers and may be associated with the increase in coronary heart disease in these people. The study demonstrates the value of the technique in assessing the effects of various drugs, especially vasodilators.

**Location of perforating varicose veins.** Patel and Williams (1971) showed that thermography could be used to locate incompetent perforating veins. With colour thermography their detection is even simpler and a series of patients is being studied to compare the efficiency of phlebography and thermography and to assess which of the various surgical methods of treatment is most effective.

The limb is cooled with towels dipped in ice water after elastic bands have been placed round the ankle and mid thigh to act as tourniquets for the superficial venous system. The patient is asked to exercise the foot against resistance to force blood from the deep to the superficial systems if incompetent perforating veins are present. These show as discrete areas of increased temperature which are easily marked indicating the site of the perforators (Fig. 9). The patient also has a phlebogram and suspected perforators are again marked. A vascular surgeon involved in the investigation treats the lesion by one of the established methods.
Efficiency of the thermogram or phlebogram is established by operative findings. The success of the operative procedure is assessed by further thermography several months post-operatively to see if all the incompetent perforators have been dealt with satisfactorily. Figures from the trial are not yet available but the accuracy of the thermographic findings have been described as extremely promising.

Fig. 8. Thermogram of a hand with Dupuytren's contracture of little, ring and middle fingers. The little finger being most affected and bent over. The middle the least. The thermogram shows the progressively poorer blood supply as the contracture becomes more severe. The palm in black is warmer than the temperature range.

Fig. 9. Thermogram of a lower limb which shows a discrete "hot spot" in white overlying an incompetent perforating vein. The patient had previously had a Cockett's operation and the scar extended to within 1 inch of the perforator. Varicose ulceration persisted post-operatively. After location and ligation of this vein the patient's varicose ulcer had remained healed for 2 years.
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CONCLUSION

Our experience shows that in a plastic surgery unit with a burns centre and an active interest in research, a thermographic camera is a worth-while investment. Not only will it improve the treatment of patients with burns and pedicles but also provides a research tool which may produce answers to several outstanding problems.

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REFERENCES

