

Quantitation of thermography in arthritis using multi-isothermal analysis

I. The thermographic index

A. J. COLLINS*†, E. F. J. RING*, J. A. COSH*, AND P. A. BACON*

From the *Royal National Hospital for Rheumatic Diseases, Bath, and the

† Pharmacology Group, University of Bath

Thermography can be used for the assessment of joint involvement in inflammatory arthritis. Modern thermographic apparatus allows temperature to be measured to within 0.2°C. and simultaneously records the areas involved. It has been demonstrated that thermographic changes in skin temperature over areas of chronic inflammation properly reflect changes in other chemical and cellular processes in rheumatoid arthritis (Ring and Collins, 1970; Collins and Cosh, 1970). The method also agrees with the findings of joint scans after technetium injection (Cosh, Lindsay, Rhys-Davies, and Ring, 1970) and correlates with the intra-articular temperature taken by thermistor probe (Lloyd-Williams, Ring, and Cosh, 1970). Recently Pinder and Ring (1974) have shown that thermographic recordings accurately locate areas of inflamed synovial tissue as shown at synovectomy.

The effect of anti-inflammatory compounds on joint inflammation in animals has been quantitated using radiometry (Collins and Ring, 1972). Thermography provides more information about the distribution of temperature. We wish to report a method for the quantitative measurement of joint inflammation in man, using thermography.

Method

THERMOGRAPHIC APPARATUS

The apparatus used was the Bofors Thermograph (Ring, 1971). The thermographic image was photographed from the cathode ray display tube on to 35 mm. colour film. Isothermal patterns, at 0.5°C. intervals, were photographed through coloured filters to produce a single multi-isothermal picture of skin temperature. Each isothermal area was represented by a separate colour. All thermograms were taken in a special room which was draught-free, shielded from direct sunlight, and maintained at a constant temperature of 20°C. The patients were seated in this controlled environment, with the limb to be examined unclothed, for not less than 20 minutes before thermography.

Patients having undergone recent physiotherapy were excluded. On each occasion, the magnification of the image

produced on the display apparatus was fixed by maintaining a constant patient-camera distance.

QUANTITATION OF DATA

The data produced from the thermograms by this method were processed in two ways:

- (1) By graphical illustration of the thermal profile before and after anti-inflammatory therapy. The area involved at each isothermal step was plotted in histograms derived by measuring the area of each isotherm after projection to life size. This diagrammatic layout produced a profile displaying both temperature and area.
- (2) The production of a single figure thermographic index.

A thermographic index was calculated from the expression:

$$\frac{\sum(\Delta t \times a)}{A}$$

where (i) Δt = Difference between the measured isothermal temperature and a constant, 26°C. This was chosen as the lowest common isotherm recorded from a series of 34 normal joints observed on one to three separate occasions.

(ii) a = Area occupied by isotherm (sq. cm.).

(iii) A = Total area of thermogram (sq. cm.).

Thus, in any thermographic profile, the thermographic index was the summation of the products of difference in temperature from 26°C. to each isothermal temperature, and the areas of each isothermal area, divided by the total area measured. In the cases recorded, $A = 100$ sq. cm., a square, 10 cm. \times 10 cm. recorded from the frontal aspect of the knee, with the patella approximately at the centre.

PATIENTS

Patients with classical or definite rheumatoid arthritis, with current acute inflammation in one knee joint, were studied. Eight patients were studied before and after a single intra-articular injection of 100 mg. methyl prednisolone triacetate (Ultracortenol, Ciba). Four patients were followed by serial thermograms on four to eight occasions, for up to 20 days. Four other patients were thermogrammed at 7 days only.

Data on the thermographic patterns of normal knees were obtained from 32 healthy male and female volunteers in the age range 20 to 56 years.

Results

Comparison of isothermal patterns and thermographic index, after corticosteroid therapy

The isothermal pattern of the inflamed knee, before and after treatment, is compared with the analysis of thermal area, and the thermographic index derived from this is shown in Fig. 1 (opposite).

It can be appreciated from the analysis, that the inflamed knee shows a wide range of temperature zones, which contracts markedly after treatment. Also, the peak temperature of 32.5°C. before treatment, which only occupies a small area, falls to 30.0°C. after treatment. The thermographic index, which reflects both the range and the peak of temperature, falls with treatment.

Initially, nine isotherms were present, but after treatment these were reduced to five, with nearly 50 per cent. of the area at 28.5°C.

The thermographic index derived from the sequential study of four knee joints is shown in Fig. 2. It is apparent that the initial thermographic indices were similar in these four patients with inflamed knees. They made a rapid initial response at about the same rate, but to different degrees of maximum improvement. The duration of the improvement was also variable, but when each patient was followed to clinical deterioration, the thermographic index had returned to about the initial value.

The thermographic index for all eight patients, before and 7 days after steroid injection, is compared with the figures for the 32 normal knees in Fig. 3. The indices in the rheumatoid knees before treatment showed a mean of 3.77, and a significant fall to a mean of 2.45 after treatment. Before treatment the figures were all above the normal range. After treatment, some of the indices were within the upper limit of the

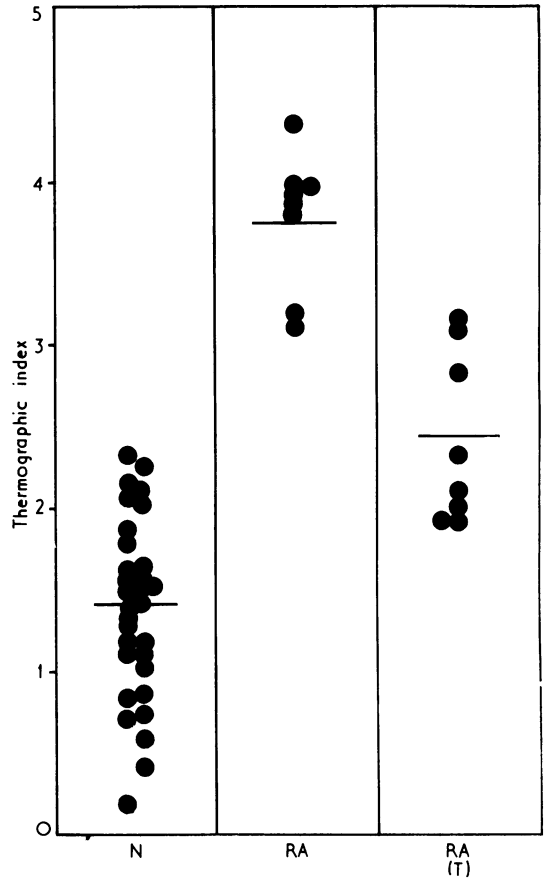


FIG. 3 Thermographic indices of normal (N), active rheumatoid (RA), and rheumatoid knees 7 days after intra-articular injection of 100 mg. TMPA (RA(T)). The mean index of the active RA group differs significantly from the treated group ($P = 0.01$)

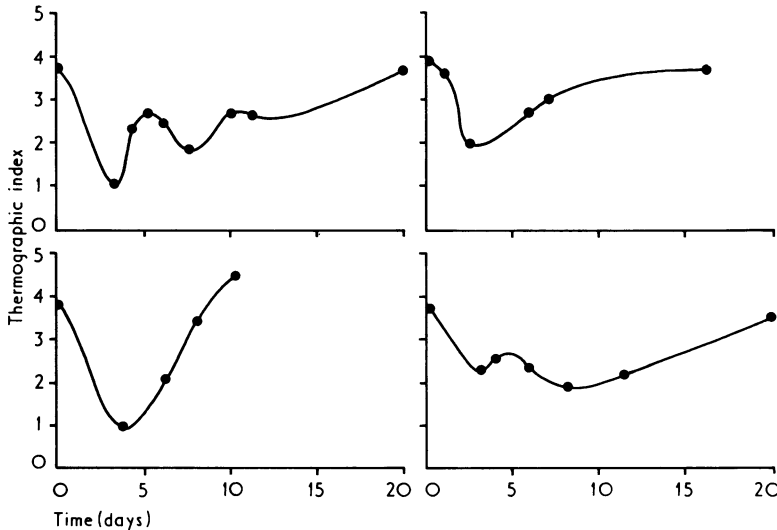


FIG. 2 Sequential plots of thermographic index taken from four rheumatoid knees after an intra-articular steroid injection, given after the calculation of the first point. Subsequent variation in the index, plotted against time in days, illustrates the differing responses, in time and degree, to the therapy

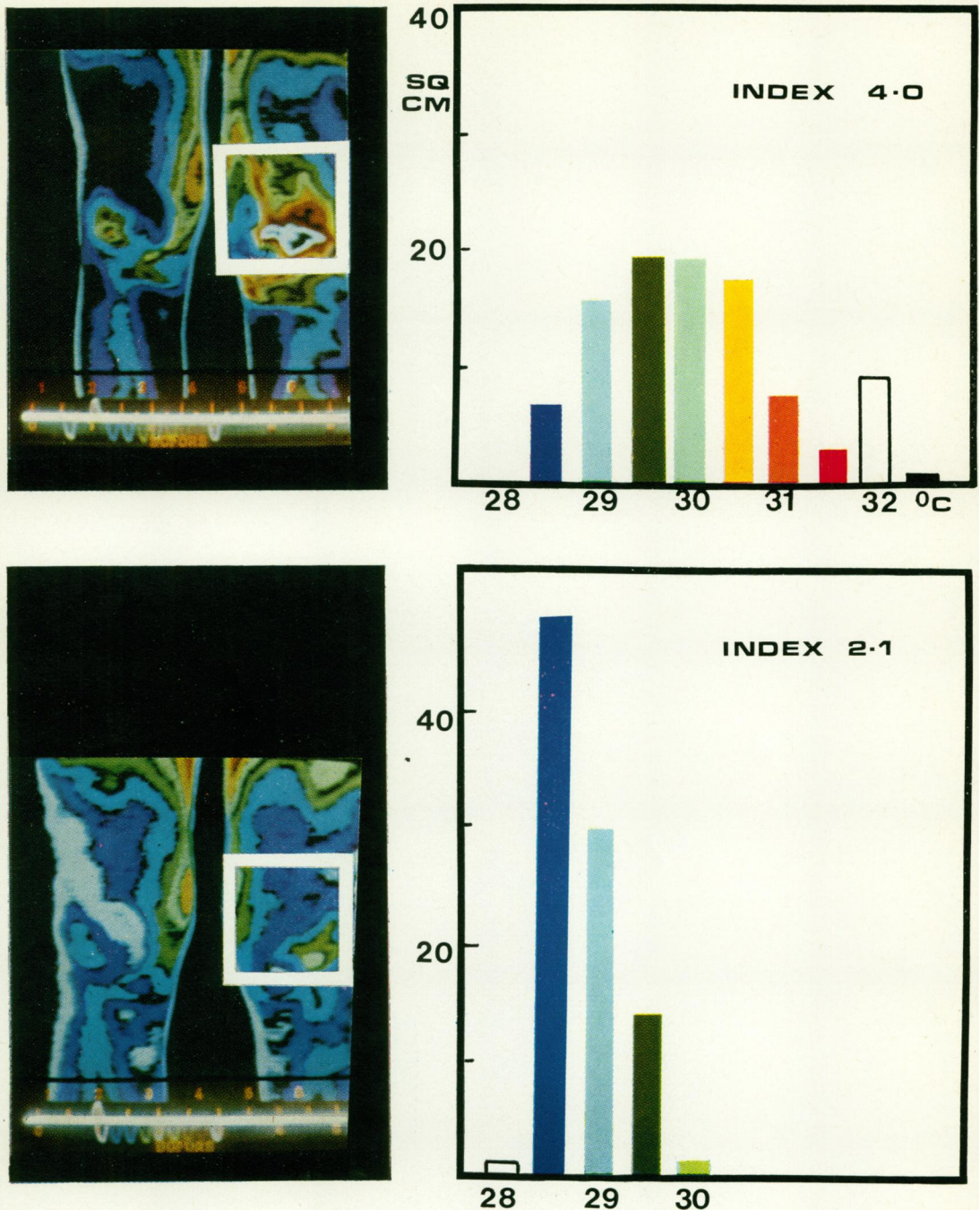


FIG. 1 (A) Comparison of the thermogram, the isothermal analysis, and single figure thermographic index derived from an area 10 cm. square, outlined in white, obtained from an inflamed knee before treatment (B) The same, 7 days after a single intra-articular injection)

of 100 mg. trimethyl prednisolone acetate (TMPA). This produced a change in the thermogram and a pronounced shift to the blue (colder) end of the temperature scale, shown by isotherm analysis. The anti-inflammatory effect of the steroid is also reflected in the lower thermographic index

scatter observed in the normal subjects. It is appreciated from Fig. 2 that 7 days is not, in fact, the time of maximum improvement.

Discussion

Modern thermographic techniques allow the pattern of inflammation in a rheumatoid joint to be demonstrated in considerable detail. The improvement in an individual joint after a single treatment can be appreciated visually, but comparison between patients or regimes has been difficult. The total thermogram is valuable in that it relates the pattern of inflammatory activity to the anatomy of the joint but, in assessing the overall response to therapy, such fine detail is not required. The isothermal analysis displays the information in a more logical fashion, but there are still difficulties in comparison between patients. The thermographic index described here reflects both the peak temperature of the joint and the area of each temperature band. We have shown that, by reducing the complex isothermal pattern to a single unitary index, the response to treatment can be quantitated.

Close control of ambient temperature and adequate patient stabilization are essential requirements for accurate serial readings. Huskisson, Berry, Browett, and Balme (1973) found that thermography did not compare well with other methods of assessing anti-inflammatory therapy when the ambient temperature

varied. This finding supports our view that, for successful sequential thermography, a controlled patient environment is essential. However, the technique can be readily repeated because as a method it is harmless to the patient. Experience has shown that the method elicits full patient co-operation.

This report has been confined to the demonstration of a method of quantitation of anti-inflammatory activity. Local steroid injection was chosen as an accepted potent anti-inflammatory against which to test the methodology. In our experience, the effect of oral non-steroidal anti-inflammatory agents can also be demonstrated with the thermographic index and this can be correlated with other clinical measurements. This will be the subject of a separate communication.

Summary

A method for the quantitative measurement of joint inflammation in man is described. Multi-isothermal scans of joints are obtained by thermography. By analysis of the isothermal areas, a thermographic index is produced. This index is demonstrated by following the course of intra-articular steroid therapy.

We should like to acknowledge the generous support of the Arthritis and Rheumatism Council for Research and of the South West Regional Hospital Board.

References

- COLLINS, A. J., AND COSH, J. A. (1970) *Ann. rheum. Dis.*, **29**, 386 (Temperature and biochemical studies of joint inflammation)
- AND RING, E. F. J. (1972) *Brit. J. Pharmacol.*, **44**, 145 (Measurement of inflammation in man and animals by radiometry)
- COSH, J. A., LINDSAY, D. J., RHYS DAVIES, E., AND RING, E. F. J. (1970) *Ann. rheum. Dis.*, **29**, 691 (The technetium scintigram as an indicator of synovial vascularity in rheumatoid arthritis: Its comparison with the results of temperature measurement)
- HUSKISSON, E. C., BERRY, H., BROWETT, J. P., AND BALME, H. WYKEHAM (1973) *Ann. rheum. Dis.*, **32**, 99 (Comparison of technetium clearance and thermography with standard methods in a clinical trial)
- LLOYD WILLIAMS, F., RING, E. F. J., AND COSH, J. A. (1970) *Ibid.*, **29**, 196 (Assessment of the anti-inflammatory effect of intra-articular steroids by means of external temperature measurements)
- PINDER, I. M., AND RING, E. F. J. (1974) *J. Bone Jt Surg.*, **56B**, in press
- RING, E. F. J. (1971) *Brit. J. hosp. Med.*, **5**, Equipment Suppl. (May), p. 24 (Equipment for medical thermography)
- AND COLLINS, A. J. (1970) *Rheum. phys. Med.*, **10**, 337 (Quantitative thermography)