SYMPOSIUM ON THERMOGRAPHY OF BONE AND JOINT DISEASES *

1. Historical introduction: thermography in Bath

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SUMMARY. The history of Bath as a centre for the treatment of rheumatic diseases is outlined. Developments in thermography in Bath have centred largely on rheumatology as well as on breast cancer and circulatory disorders. These developments are reviewed, and techniques for quantitation in thermography are described.

Key words: thermography; radiometry; rheumatology; anti-inflammatory drugs.

A) INTRODUCTION

We welcome the members of the European Thermographic Association to the clinical section of our congress, at the Royal Natjonal Hospital for Rheumatic Diseases, Bath. We feel that this hospital and this city make an appropriate centre for the Association's first meeting in this country as we have been involved here in the clinical applications of thermography for several years, especially in the fields of rheumatology and breast cancer.

1) Bath's History. There are historical reasons too why Bath is a good centre for our meeting. Because of its hot springs Bath has been a therapeutic centre for nearly 2,000 years, particularly for sufferers from rheumatic diseases. Some 2 million litres of water flow daily from the hot springs, with a constant temperature of 49°C. The Romans built their first bath system here in the first century AD, and the visitor today can see the extensive remains of the complex of buildings remaining from the 4 centuries of their rule here. Near the baths stood the temple dedicated to Sul-Minerva, for the Romans identified the local goddess Sul with Minerva, and named the city after her, Aquae Sulis.

After the departure of the Romans in the 5th century their buildings fell into ruins, and the main hot bath was completely lost until uncovered during rebuilding in the 19th century. But the waters, of course, continued to flow, and in Saxon and mediaeval times were being used again. The Abbey was founded in the 10th century, and the city was rebuilt; the Kings Bath and the Cross Bath were constructed and a continuous stream of visitors came to the city to bathe in its waters. There are many accounts of the medical use of the waters in past centuries, notably that of Leland in 1540, particularly for the treatment of bone and joint disease.

Following visits by royalty in the 17th and 18th centuries, Bath became a leading fashionable resort for the sick, and to accommodate the influx of visitors the city grew rapidly. Splendid terraces and crescents were built, using local stone, and it is the Georgian architecture of this era which still characterizes the city today. The city's unprecedented popularity in the 18'" century led to crowded social scenes and events in which

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* On the 9th and 10th April, 1976 the groups on Terminology and Teaching, on Industrial and Ecological Thermography, on Biothermometrology, the Executive Committee and the National Delegates of the European Thermographic Association met in Bath (England).

In that occasion a Symposium devoted to bone and ioint diseases was held at the Roval National Hospital for Rheumatic Diseases.

E. F. J. Rinn of the Roval National Hosnital for Rheumatic Diseases was "the President.

the visitors behaviour often left much to be desired. This was remedied by the firm regulations imposed by the master of ceremonies, Beau Nash, who introduced a strict code of manners for all who attended receptions in the Assembly Room, or who visited the Pump Room and Baths. It was Beau Nash who strongly supported the building of a hospital to house the sick poor visiting the city, and it was that hospital, opened in 1742, which has grown on the same site, into the Royal National Hospital for Rheumatic Diseases, where this part of our conference is now being held [7].

2) Sir William Herschel. At a meeting in Bath devoted to thermography we must make mention of William Herschel (Fig. 1). He was born in Hanover in 1738, came to England as a musician, and took the post of organist in the newly built Octagon chapel in Bath in 1766. While living here he developed his interest in astronomy, and it was in Bath that he discovered the planet Uranus with a telescope of his own making. After leaving Bath in 1788 he turned his wide ranging ingenuity to a study of the solar spectrum, and noted the transmission of heat in the infra-red zone beyond the visible spectrum. He is justly, therefore, recognized as the discoverer of infrared radiation. He was knighted in 1816, became president of the Royal Astronomical Society, and died in 1822. During this brief conference we have had the pleasure of meeting in the Octagon Hall, now no longer a chapel, where we heard a music recital given by the Herschel ensemble, which included compositions by Sir William Herschel himself.

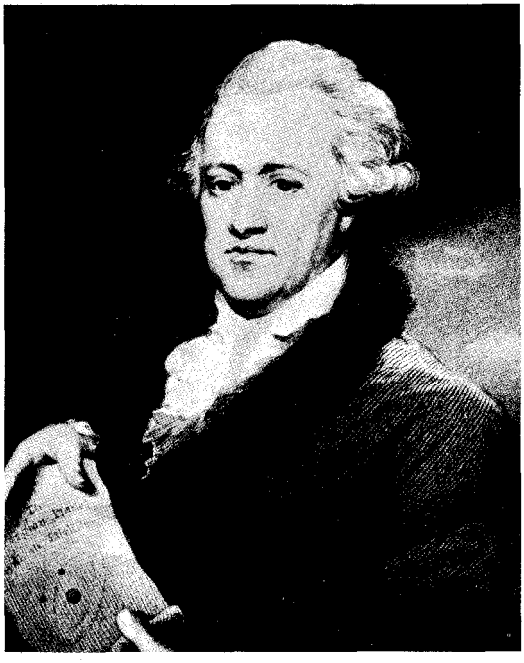

Fig. ***1. Sir William Herschel*** 1738-1822. Astronomer Royal and discoverer of the planet Uranus, who first described the transmission of heat in the infra-red portion of the solar spectrum. He came to Bath as musician and organist in 1766.

B) THERMOGRAPHY IN BATH

Our interest in thermography and its possible use in rheumatology was awakened in 1963 when the first thermographic camera became available in Britain. This was the Smith's Pyroscan, originally conceived as a possible navigational aid by infra-red scanning, and then developed for industrial and medical uses [2]. We found that in spite of its limitations, this thermograph would demonstrate changes in peripheral blood flow such as reactive hyperaemia following temporary arterial occlusion, and would also show abnormal temperature patterns due to inflammation in the skin or in underlying joints. We soon appreciated the need for standardization of environmental conditions for thermography, and we were fortunate that hospital reconstruction enabled us to set up a suitable temperature-controlled room in 1965 [6,9].

At this time Lloyd Williams was studying breast cancer by infra-red detection at the Middlesex Hospital, London, confirming the original observations of Lawson [14]. He established a relationship between the raised temperature of the skin over a breast tumour, measured with a distant thermistor, and the degree of malignancy of the tumour [17].

1) Radiometry

Following the work of Lloyd Williams we acquired a radiometer and used this in our studies of inflammation[26]. We compared the skin temperature over the knee with the intra articular temperature in rheumatoid arthritis, and showed that application of an ice pack to the skin caused a slight

fall in the intra articular temperature. After removal of the ice pack the external and internal temperaturea rose gradually to their original level over about 20 minutes. The more acute the inflammation, the more rapid was the rewarming process. Injection of steroid into the knee caused a fall in the external and internal tcmperaturcs as described by Horvath and Hollander [13], and the rewarming process after ice became slow once more, as in a normal knee [15]. We found too that an isotope scan of an inflamed knee, using I.V. technetium, revealed visually the intensity and site of inflammation; a day or two after an intra articular injection of steroid the reduction in intensity of isotope pattern was closely parallel to the fall in temperature of the joint' (Fig. 2).

We examined the relationship between the external temperature of an inflamed knee, mcasurcd by the radiometer, and the characteristics of the synovial fluid, obtained by serial aspiration. During the course of treatment WC found that temperature rose or Cell in parallel with the volume of synovial fluid, and with its protein content: howevcr there was no clear parallel between tcmpc-raturc and the acid phosphatase content of the fluid [3]. In animal models too, it was found that radiometry provided a simple and useful guide to the progress of inflammation and the action of an anti inflammatory drug such as azapropazone [4].

2) Thermography

The information given by radiometry is of course limited as it tells us nothing of the heat patterns in the skin, which are displayed by thermography. For over 10 years we have had a thermography laboratory at this hospital where we have been mainly concerned with the applications of thermography in rheumatology. Most of our experience has been with the Bofors instrument, but we have also made use of the Aga [10].

Another thermography laboratory in Bath, at the Royal United Hospital, has continued to study heat patterns of the breast, the variations associated with menstruation, contraceptive hormone therapy, and the detection of breast cancer [16]. Other subjects studied have included varicose veins in the leg, with the detection of points of communication between superficial and deep veins [18, 19] and heat patterns of the face and forehead in patients with occlusive lesions of the internal carotid artery [20], [21].

Owing to this activity in the two laboratories in Bath we have had experience of a number of different thermographic scanners. These have included the Rank and the EMI instruments, and the government prototype made by AWRE, Aldermaston and Barr and Stroud. This has enabled Ring to make a careful and critical evaluation of the features of many such instruments [22]. He paid particular attention to sensitivity, definition of display and stability of the instruments reviewed. Once again, as a result of this

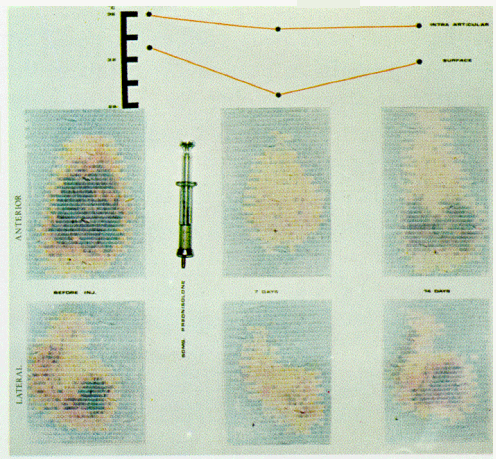

Fig. 2. Technetium scintigrams, anterior and lateral, of knee joint in a patient with rheumatoid arthritis. The acutely inflamed, highly vascular svnovium produces intense localization of the isotope (left). 50 mg of prednisone was injected intra-articularly, with marked reduction of inflammation and vascularity 7 days later, and a return of inflammation at 14 days. The associated fall and later rise of skin temperature, measured by radiometer is shown above, with the corresponding, much slighter, fall in intra articulal temperature measured by thermistor.

review, we were reminded of the importance of stability in the instrument, standardization of environment in the thermography room, proper preparation of the patient, and the need for a standard temperature reference source for inclusion in the thermogram. Moreover, physiological diurnal variations in temperature must be borne in mind. Variations appear to be least in the morning hours, which are therefore preferred for any serial clinical studies[23].

Our main application for thermography in this hospital has been in the study of rheumatoid arthritis and similar forms of inflammatory polyarthritis. We have been fortunate in that the large number of patients undergoing knee synovectomy has made it possible to compare pre-operative thermograms of the knee with the intra-articular appearance seen at operation [11'23]. In a series of 100 patients so studied, Pinder and Ring consistently found a close relationship between the sites of maximum synovial vascularity within the knee (which are subject to considerable individual variation) and the superficial heat pattern revealed by thermography. In a number of instance, the thermogram was of value in directing the surgeon's attention to regions of the synovium requiring special attention at operation.

For serial thermographic studies of inflammatory arthritis and its response to treatment, it is essential to have some form of quantitation of the thermogram. Up to a point this can be achieved by used of a line scan, or by following changes in a single isothermal area [24]. However, methods based on measurement of areas of isotherms are difficult and time consuming, and only become practicable if a computerized technique is available.

We were able to link a cathode ray display tube and a Nukab computer to our Bofors thermograph in 1973, and have dealt with the problem of quantitation in this way. In the first place, this equipment produces a point by point and line by line print-out of skin temperatures in any required area of the completed thermogram. This thermogram can be retained indefinitely in the computer memory, or stored ready for recall at a later date. Simpler still, the « thermographic index » can be calculated and recorded virtually instantly for any required portion of a completed thermogram. This thermographic index is derived from the areas of the isotherms displayed within the portion, or area, being analysed'. Such a figure, indicative of the acuteness of inflammation in an affected joint, can be recorded as often as necessary during the course of joint disease, or throughout a period of treatment, with perfect safety to the patient. It has been applied in the assessment of non steroid anti-inflammatory drugs [25] and in the comparison of the effects of different steroids injected intra articularly [12].

Clearly, thermography now has much to offer in this aspect of the field of clinical pharmacology' in that it provides a safe, repeatable method for an objective assessment of inflammatory disease and its response to treatment.

REFERENCES

1. BACON P. A., COLLINS A. J., RING E. F. J., Cosh J.A.: Thermography in the assessment of inflammatory arthritis. ***Clin. Rheum. Dis., 2,*** 51-65, 1976.
2. CADE C.M.: High-speed thermography. ***Ann. N. Y. Acad. Sci.,*** 121, 71-79, 1964.
3. COLLINS A. J., COSH J. A.: Temperature and biochemical studies of inflammation. ***Ann.*** Rheum. Dis., 29, 386-392, 1970.
4. COLLINS A. J., RING E. F. J.: Measurement of inflammation in animals and man by radiometry. ***Brit. J. Pharmacol, 44,*** 145-152, 1972.
5. COLLINS A. J., RING E. F. J., COSH J. A., BACON P. A.: Quantitation of thermography in arthritis using multi-isothermal analysis. I The thermographic index. ***Ann. Rheum. Dis., 33,*** 113-l 15, 1974.
6. COSH J.A.: Infra-red detection in the assessment of rheumatoid arthritis. ***Proc. roy. Soc. Med.,*** 59, Suppl. on Measurement in Therapeutic Assessment, 88-93, 1966.
7. COSH J. A., KERSLEY G. D.: Rheumatic treatment centres in Britain: Bath, ancient and modern. ***Ann. Phys. Med.,*** 10, 167-174, 1969.
8. COSH J. A., LINDSAY D. J., RHYS DAVIES E., RING E. F. J.: The technetium scintigram as an indicator of synovial vascularity in rheuma-

toid arthritis: its comparison with the results of temperature measurement. ***Ann. Rheum. Dis.* 29,** 691, 1970.

9. **Cosh** J. A., **Ring** E. F. J.: Techniques of heat detection used in the assessment of rheumatic diseases. ***J. Radiol. Electrol., 48, 84-89,*** 1967.
10. **Cosh** J. A., **Ring** E. F. J.: Thermography and rheumatology. ***Rheumatol. and Phys. Med.,* 10, 342-348,** 1970.
11. Cosh J. A., **Ring** E. F. J., **Collins** A. J., **Pinder** I. M.: Application of radiometry and thermography in rheumatic diseases. ***Excerpta Medica*** 299: XIII International Congress of Rheumatology, Kyoto. Abstract 653,-1973.
12. **Esselinckx** W., **Demottaz** D., **Ring** E. F. J., **Collins** A. J., **Bacon** P.A.: Comparison of intra articular steroids in rheumatoid arthritis by thermography. In press. 1976.
13. **Horvath** S. M., **Hollander** J. L.: Intra articular temperature as measure of joint reaction. ***J. Clin. Invest., 28, 469-473, 1949.***
14. **Lawson** R.N.: Implications of surface temperature in the diagnosis of breast cancer. ***Canad. med. J., 75, 309,*** 1956.
15. **Lloyd Williams F., Ring** E. F. J., **Cosh** J. A.: Assessment of anti inflammatorv effect of intra articular steroids by means of external temperature measurement. ***Ann. Rheum. Dis., 29,* 196,** 1970.
16. **Lloyd Williams** K.: Thermography in the prognosis of breast cancer. ***Bibl. Radiol., 5,*** 127-129, 1968.
17. **Lloyd Williams** K., **Cade** C. M., **Goodwin** D. W.: The electronic heat camera in medical research. ***J. Brit. I.R.E., 25,*** 241-250, 1963.
18. **Patil** K. D., **Lloyd Williams** K.: Thermographic study of heat flow in the detection of incompetent perforating veins. ***Surg. Gynaec. Obstet.,* 132, 396-402,** 1971.
19. **Patil** K. D., **Williams** J. R., **Lloyd Williams** K.: Thermographic localization of incompetent perforating veins in the leg. ***Brit. med. J.,* 1,** 195-197, 1970.
20. **Phillips** B. H., **Lloyd Williams** K.: An evaluation of thermography in carotid insufficiency. ***Proocedings of international conference on blood flow measurement.*** Sector publishing, London, 1974.
21. **Phillips** B.H., **Lloyd Williams** K.: The clinical uses of thermography. ***Brit. I.*** *Hosp.* ***Med. (Equipment supplement) 1974.***
22. **Ring** E. F. J.: Equipment for medical thermography. ***Brit. J. Hosp. Med. (Equipment supplement), 5, 24-28, 1971.***
23. **Ring** E. F. J.: Thermography and rheumatic diseases. ***Bibl. Radiol., 6, 97-106,*** 1975.
24. **Ring** E. F. J., **Collins** A. J.: Quantitative thermography. ***Rheumatol. Phys. Med.,* 10, 337-341, 1970.**
25. **Ring** E. F. J., **Collins A. J., Bacon P.** A., **Cosh** J. A.: Quantitation of thermography in arthritis using multi isothermal analysis. II Effect of nonsteroidal anti inflammatory therapy on the thermographic index. ***Ann. Rheum. Dis., 33, 353-356, 1974.***
26. **Ring** E. F. J., **Cosh** J. A.: Skin temperature measurement by radiometry. ***Brit. med. J., 4,*** 448-449, 1968.