Power in the upper limbs was normal and there were no changes in the tendon reflexes. There was a marked hyperalgesia in the skin of the upper limbs and a distaste for handling of the limbs. No sensory loss could be made out. Crepitations were present on movement of both shoulder-joints. The drawing of a pin along the skin of the forearms and back of the hands produced an intensely disagreeable sensation and a gross exaggeration of the "flare" of the "triple response," which persisted for over an hour. In other parts of the body this procedure produced only a normal flare. A radiograph of the heart and cervical spine showed no abnormality, and an electrocardiogram was normal. The blood pressure was 120/80 mm. Hg and the pulse regular.

The patient was advised to rest in bed lying flat with the arms in slings, and acetyl-salicylic acid, 10 gr. (0.65 g.), was given three times a day. After a month the pains and the anginal symptoms had disappeared, though the hands were still swollen on waking in the morning. After a further month, using the limbs as little as possible, there was still slight swelling of the hands on waking. When seen a year later his symptoms had completely disappeared.

In this case there was no evidence of coronary disease, but the arm was painful and hot, and its tissues showed marked vasodilatation. The flare of the triple response was very easily obtained on the affected skin. This vasodilator nervous activity must involve deep tissues supplied by the affected roots and D 1-2 roots, supplying the coronary vessels.

Conclusion

In all cardiac conditions in which angina or coronary pain is experienced there is evidence of excessive activity in the vasodilator pain fibres passing to the coronary vessels, and this is evidently the origin of the anginal pain. Lesions of the derivatives of the septum transversum have also been shown to cause angina. Their nerve supply from the posterior nerve roots is established very early in development, and the nerve supply of the derivatives is therefore closely related if not identical. The mediastinal tissues are supplied with vasodilator fibres by way of D 1-5 posterior nerve roots, which also supply the heart. Lesions of these, as of other tissues, result in an increased activity in the vasodilator fibres passing in the same nerve roots as supply the coronary vessels. Hence any lesion of either mediastinum or heart which causes an increased activity in vasodilator pain fibres may result in angina. Such a conception brings angina into line with other painful conditions, such as headache, resulting from excessive vasodilatation in blood vessels. Thus angina is not directly due to anoxia or to vasoconstriction but to excessive attempts at vasodilatation.

The activity of any organ, including the heart, is accompanied by a reflex hyperaemia and by arterial vasodilatation, which occurs through the agency of vasodilator nervous impulses. The afferent nerve endings are stimulated by metabolites. Coronary sclerosis prevents vasodilatation during increased cardiac activity and allows the collection of metabolites. These cause excessive numbers of reflex impulses in the coronary vasodilator pain fibres in an attempt to produce further vasodilatation, and it is this excessive nervous activity which appears to give rise to the pain in such conditions.

Summary

Evidence is adduced to show that anginal pain may be caused by disease of both the tissues of the mediastinum and the heart. It seems to be due to excessive activity in the vasodilator pain fibres in the posterior nerve roots passing to the mediastinal structures and the coronary vessels, and it is not necessarily due to anoxia.

I would like to thank Dr. P. E. Thompson Hancock for permission to publish the details of Case 1.

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TOLERANCE LIMITS TO RADIANT HEAT

BY

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Radiant heat, a combination of visible and infra-red radiations, plays an important part in the practice of physiotherapy. In spite of this widespread use there have been few studies on the optimal and curative effects of measured amounts of radiant heat. The usual method of regulating the dosage of radiant heat is briefly to adjust the source used (incandescent filament bulb or resistance-wire heating element) at a distance from the patient's skin so that he feels comfortably warm but will be free from any hazard of burn. Since the conditions under which a burn will occur are poorly defined, it is necessary always to err on the side of safety.

It is perhaps not generally realized that heat is more easily administered by radiation than by convection and that accurate dosage can be prescribed (Evans and Mendelsohn, 1945a). A series of investigations carried out in this department and at the Clarendon Laboratory, Oxford, have led to the development of a suitable instrument for measuring radiation flux, including all visible and infra-red radiation (Evans and Mendelsohn, 1944, 1945b). The aim of the present investigation was to use this thermoradiometer for the determination of tolerance limits of the

human skin to heat radiation. In order to isolate the basic problem we have so far limited ourselves to the local application of radiation from an incandescent filament lamp, and to the effect produced on healthy volunteers. Establishment of such a normal tolerance limit will form a base-line on which the clinical applications can be established.

Method

Tolerance limits were determined by exposing a given area of skin surface for a measured time to a radiation flux determined by the subjective reactions and by the skin surface temperature. At the end of each test the radiation flux tolerated under these standard conditions was measured by the thermo-radiometer.

The skin locations chosen were areas of 12×12 cm. in the epigastrium and in the interscapular area. Each was exposed to an ordinary clinical radiation source (1,000-watt tungsten-filament bulb set in a concave reflector) operated at constant full strength. Energy profiles were plotted to examine the radiation flux in detail, and these showed a fairly even distribution of radiation flux over the exposed area.*

With the exposure of an area of measured size the input could be calculated from the thermo-radiometer reading in quantitative physical units and an accurate estimate of the dosage obtained. A screen was constructed of asbestos board (insulating layer) with copper sheeting on top (reflecting layer), in the centre of which a square aperture of 12×12 cm. was cut. This screen was placed almost in contact with the subject's skin, and so determined the area exposed. An area of this size was chosen as it was found that with smaller areas (4×4 cm. and less) the radiation flux tolerated depended inversely on the size of the area. An area such as used in this work also more closely approximated conditions in clinical practice.

The epigastric and interscapular areas were chosen as they provided large relatively flat skin surfaces. Because the skin in these two areas differs in thickness, adiposity, and sensitivity, it was to be expected that in comparing these areas any differences in tolerance limits due to these factors would be thereby discovered. Separate experiments were carried out on various parts of the body. These showed that the variation was slight and would not alter the general conditions as given below. A detailed report will be published later.

The thermo-radiometer used was that described by Evans and Mendelssohn (1945b). It has been designed to measure all the visible and infra-red radiation. At the end of each test exposure the thermo-radiometer was put under the screen aperture in the place occupied by the subject's skin and the radiation flux measured, the lamp and screen being in the same relation as during the test. The radiation flux was recorded in gramme-calories per square centimetre per minute, termed by us, for simplicity, "pyrons" (1 pyron = 1 gramme-calorie flowing through 1 square centimetre in 1 minute).

Skin Temperature

As it was thought that there might be variations in tolerance due to apprehension or, on the other hand, due to attempts to stand more heat than others, the skin surface temperature was measured at intervals of a minute during all exposures. It was found in preliminary experiments

that under standard conditions of exposure, the skin surface reached a higher temperature than the lower skin layers, the subcutaneous tissues, or the underlying muscles. The skin surface temperature would then be the determining factor in tolerance-limits tests, and one of the most important factors to measure.

After testing several types, the skin thermometer selected consisted of fine copper and constantan wires threaded through a hypodermic needle and soldered together at the tip to form a thermo-junction. This is the method used by Mendelssohn and Rossiter (1944), who have discussed the accuracy and reliability of such a device, with a difference, however, that in our main investigation the tip of the needle was not inserted into the skin but laid on it without exerting pressure. Comparison tests with other types of thermometer showed that in this way skin temperature would be reliably recorded even in the presence of impinging radiation. The leads from the thermocouple were connected in circuit to a galvanometer and to a constant temperature reference junction maintained at 37°C .

With given exposure of radiant heat the skin surface temperature was found to rise rapidly for the first three to five minutes and then to reach a constant temperature—an equilibrium skin temperature at which heat inflow was balanced by heat dissipation (conduction, vasodilatation, and perspiration). The exposure was continued until the skin had continued at equilibrium temperature for ten minutes. This was long enough for the subject to be certain he could tolerate the radiation comfortably. It had been found in preliminary tests that if a certain radiation flux could be tolerated for this length of time it could be tolerated for longer periods, up to 20 or 25 minutes and probably longer. In measuring skin temperatures it was essential to avoid causing air currents to move over the field of exposure. Draughts were excluded from the room, and talking or the moving of objects close to the field of exposure was avoided.

Definition of Tolerance Limits

For the purpose of this investigation the tolerance limit to radiant heat was defined subjectively as the maximal amount that could be tolerated with comfort. In the testing this involved gradually approaching the intensity level of discomfort with slight prickling or mild burning sensation, and then reducing the intensity until the subject was quite certain that the radiant heat was tolerable without discomfort. The equilibrium skin temperature was then observed for ten minutes and the mean value calculated. Variations of equilibrium temperatures from the mean were very small. The thermo-radiometer gave the corresponding intensity of the radiation flux at the end of the exposure, and this, with the mean equilibrium skin temperature, was used to define the tolerance limit objectively.

The effects of this dosage of radiant heat on temperature, pulse, respiration, and blood pressure were measured, as it was considered that changes in these physiological factors might influence tolerance. However, the only significant change was a slight rise in oral temperature (average of 0.6°F . (0.33°C .) in 30 of 38 subjects tested), and it was concluded that these factors were unimportant in defining tolerance limits under our conditions of exposure. Any small effect of heating on the pulse, respiration, and blood pressure was obscured by the effect of rest and diminished apprehension as the test proceeded. The test procedure, including the two exposures to radiant heat of about 15 minutes' duration, was carried out on 40 healthy adult volunteers of both sexes. The observations on skin temperature and radiation flux at tolerance limits are presented below.

*We are indebted to Hanovia, Ltd., for the loan of a "Sollux" heat lamp used in this investigation. The reflector of this lamp has a slightly granular finish which in comparison with most treatment lamps has the great advantage of not producing focused "hot spots." This was of particular value in our investigation, since the tolerance depends on the maximum radiation flux anywhere in the field of exposure. Treatment lamps with radiation field containing hot spots are bound to be inefficient, as the distance between lamp and patient will be determined by the warmest area of the field.

Some of the beneficial effects of radiant heat are thought to be due to an analgesic action. It was hoped that this might be subject to direct experiment by comparing the sensitivity to series of pin-pricks of the area during exposure to radiant heat with that of a control area previously reported as equivalent in sensitivity. Of 39 subjects tested in this way, 29 reported that pin-prick felt duller

over the exposure area. Of the remainder only one subject reported that pin-prick was sharper over the exposed area, while nine could detect no difference. Though this is a rather gross and approximate method of testing, it was believed to indicate that heat had a definite blunting effect on pain sensibility. This did not spread to areas with similar nerve supply, under these condi-

The difference in tolerance limits between the epigastrium and the interscapular area was small though statistically significant. The mean values of the observations on the epigastrium were 44.3°C . and 2.3 pyrons compared with 44.9°C . and 2.6 pyrons for the interscapular area (see Figs. 3 and 4). A difference of this small degree, when viewed in the light of clinical practice, would not necessitate separate dosage schedules for these areas. However, a significant difference does indicate that differences in skin structure or function, such as thickness, adiposity, pigmentation, richness of sweat glands and of nerve endings, may influence tolerance limits even though only in a small degree. The exact influence of these factors remains to be determined.

These findings are interesting when compared with previous reports. Carl Sonne (1929) studied the tolerance of five subjects to visible and short infra-red radiation for an exposure area of 3 cm. diameter on the inner side of the forearm, and found a value of 3.1 pyrons. Laurens and Foster (1937), in a study of the tissue temperature gradient under radiant heat, found that most of their subjects could tolerate 1.8 pyrons from an incandescent source, but they do not state that this was the maximum tolerable. Mayneord and Tulley (1943), using a different type of thermo-radiometer, in a series of 25 patients undergoing heat treatment found that there was a wide range of radiation intensities tolerable from 0.6 to 3.6 pyrons, but most values were about 2 pyrons. The skin temperatures were not reported. Elkins and Sheard (1941) found that, with a 250-watt heat lamp, skin temperature of $41-43^{\circ}\text{C}$. over the foot and knee could be tolerated without discomfort, but the radiation intensities were not specified.

The present findings indicate that a fairly definite tolerance limit may be determined for normal subjects under standard conditions. With such a definite value as a guide, conclusions may be drawn regarding approximate dosage levels in clinical practice. Directions for treatment intensities as given in some textbooks of physiotherapy would probably produce incident radiation flux of less than 1 pyron (Krusen, 1941; and Kovacs, 1945). A few measurements were carried out on patients undergoing clinical treatment, and the radiation flux varied from 0.75 to 1.5 pyrons. Probably the present dosage of radiant heat is inadequate (Elkins, 1946) and could be increased with

FIG. 1.—Skin surface temperatures at tolerance limits for combined series (80 observations) arranged in 0.5°C . groups, and plotted as a distribution curve. The peak of the curve is seen to occur at about 44.5°C ., and the scatter is small.

tions at least, and thus would appear to be an effect on peripheral nerve endings.

The measurements of tolerance limits, expressed in terms of the equilibrium skin temperature and radiation flux, showed a surprising uniformity. In fact our results indicate the presence of a well-defined *general* tolerance level in normal subjects. The observations have been presented as distribution curves, Fig. 1 showing skin temperatures ($^{\circ}\text{C}$.) at tolerance limits, and Fig. 2 showing radiation flux in pyrons. The main equilibrium skin temperature at toler-

FIG. 2.—Data for radiation flux at tolerance limits for combined series (80 observations) arranged in 0.5 pyron groups, and plotted as a distribution curve. The peak of the curve is seen to occur at about 2.4 pyrons, and the scatter is small.

a routine the lamp was raised and lowered several times before the final level of maximum radiation with comfort was decided, and each time the subject stated his tolerance to be at an almost identical level, although it was difficult or impossible for him to judge visually the distance of the lamp from the skin.

FIG. 3.—Separate distribution curves plotted for skin temperatures at tolerance limits for epigastric (continuous line) and interscapular (broken line) areas under standardized conditions. A statistically significant though small variation occurs between these two distributions.

FIG. 4.—Separate distribution curves plotted for data of radiation flux at tolerance limits for epigastric (continuous line) and interscapular (broken line) areas. Again a statistically significant though small variation occurs between these two distributions.

considerable advantage under carefully controlled conditions such as the measurement of radiation flux with the thermoradiometer and of skin temperature. In similar fashion, tolerance limits for various pathological conditions in which the tolerance is likely to be reduced (peripheral vascular disorders, nerve lesions, large avascular scars) could be defined, and appropriate conditions established (including dosage in measured quantitative units) for radiant-heat therapy in a wide variety of diseases.

Summary

The tolerance limit to local irradiation by visible and infrared rays has been measured in terms of radiation flux and skin temperature in 40 experimental volunteers.

There is a sharp and well-defined transition from a feeling of heat which is comfortable to a sensation of burning. The skin temperature at which this change of sensation takes place is about 45° C. (113° F.) and the tolerated radiation is of the order of 2.5 gramme-calories per square centimetre per minute. This figure is well above the usual therapeutic intensity, and we suggest that under well-defined conditions considerably higher intensities of radiant heat can be applied clinically than has been customary so far.

We should like to thank Prof. L. J. Witts for his suggestions and advice in all phases of this work. We are much indebted to Miss MacDonald, of the Dorset House School of Occupational Therapy, and to the students at the school who were such willing volunteers. Mrs. Lloyd-Smith greatly assisted in recording the experimental work.

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SUDDEN DEATH AFTER INTRAVENOUS SODIUM BISMUTH TARTRATE

BY

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Bismuth, in the form of sodium tartrate ("sobita"), is widely used in the Tropics for the treatment of yaws. The dosage varies from $\frac{1}{2}$ to 3 gr. (32 to 200 mg.), according to weight and age, given intramuscularly in aqueous solution. A series of from three to six injections at weekly intervals constitutes the usual course, and towards the end of such courses mild bismuth poisoning, as demonstrated by blue gums and gingivitis, is occasionally seen, but untoward results are very rare.

Manson-Bahr (1940) states that in Tanganyika over a million cases have been treated with this drug since 1924, and he mentions no fatalities. During the period 1933 to 1942 almost a quarter of a ton, representing more than one and a half million adult doses, has been administered in the Gold Coast, with no recorded fatalities. Dowds (1936), in Rhodesia, has reported three deaths following subcutaneous injection of sobita, but in these cases the quantities administered were very much larger than the usual dose (25, 13, and 25 gr. (1.65, 0.85, and 1.65 g.) respectively), and death occurred from six to fourteen days afterwards, renal damage being a prominent feature.

The toxicity of bismuth is stated by Smith (1934) to be ten to twenty times greater by the intravenous than by the intramuscular route. Cushny (1947) states that in mammals large doses of sodium bismuth tartrate act chiefly upon the central nervous system, causing accelerated respiration, violent convulsions, and slowing of the heart, with temporary cessation of the beat. He quotes Masson as describing a direct depressant action upon the heart with irregularities of which heart-block is the commonest.

Klauder (1923) demonstrated that in the rabbit the maximum single tolerated dose of sodium and potassium bismuth tartrates in aqueous solution by the intravenous route was 0.125 g. per kg. of body weight. There appears to be little record of the toxic effects of intravenous bismuth salts in man, although Fischer (1926) describes a case of severe bismuth poisoning, with recovery, following a course of intravenous bismuth-diasporal.

As long ago as 1925 Harrison pointed out that the technique of intramuscular injection which is commonly employed may easily result in the remedy entering a vein unless precautions are taken to prevent this, such as the separate insertion of the needle and a preliminary pull on the piston before injecting; and Chenoy (1926) records a case in which he assumes that the fatal issue was due to the accidental intravenous injection of an insoluble bismuth preparation in this manner; but perusal of this report leaves considerable doubt whether the injection was as stated, and, if it was, the effects might well have been due to embolism.

The only other case of sudden death from intravenous bismuth that I have been able to trace is that of Magnus (1924), but as I have access to only an abstract of this it is not clear to me what salt or dosage was given. The following cases may therefore be of interest.

Case Reports

Three adult female Africans each inadvertently received intravenously 10 gr. (650 mg.) of sodium bismuth tartrate in aqueous solution. Two of the women collapsed and died within

Sir George Henderson, Secretary of the Department of Health for Scotland, spoke on March 30 to the Edinburgh City Business Club on the hospital service under the N.H.S. Act. He said that the transfer to the State had been necessary in order to weld together a miscellaneous collection of hospital organizations in the interest of progress in treatment, medical education, and research; but there would be no startling changes immediately. The hospitals to be transferred were all public hospitals. Everyone in the country would be entitled to free hospital treatment as necessary, but the patient might accept parts of the Service and reject others—for example, a patient might go to a private nursing-home in a State ambulance. Progress was bound to be gradual. Building would remain difficult for some time, but at some date they would have to undertake the building of new hospitals to replace out-of-date ones. Buildings were less important than the spirit of the staff who worked in them. They confidently hoped that the great professions whose task was to heal and tend the sick and injured would co-operate freely and whole-heartedly in that important venture. It was sometimes said that they would not retain any of the spirit of voluntarism; that they would lose a lot of the kind of service so freely given to-day by public-spirited men and women. They hoped not. There were numerous ways in which voluntary effort could help the Service. There was one point on which he might correct a common misapprehension—the substantial endowment funds of many of the voluntary hospitals. In the main these funds were not being taken over by the Government. They would go to the new boards of management, who would hold them on trust and use them for purposes similar to those for which they were now held.