RADIUM TELETHERAPY

LATEST MODIFICATION OF THE WESTMINSTER APPARATUS AND ITS USE*

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(With Special Plate)

Westminster Hospital has made use of distance mass radiation with radium since 1929. In all, five different machines have been constructed and employed for treatment of patients and for research. Masses of 1 gram, 4 grams, and 2 grams have been used. Increased experience has dictated necessary modifications of the container, the distribution of radium within it, and the methods of treatment. The successive designs embody the results of our experience. A brief résumé of the earlier types will be of assistance in making clear the reasons for adopting the current form, whose successor will, no doubt, eventually incorporate further improvements.

When the work began the method of applying large quantities of radium placed outside the body was still at an early stage, and we were unable to discover that any definite principles had been laid down for guidance in the technique of treatment. For example, it was impossible to obtain any satisfactory answer to the question whether the beam of radiation should be broad or narrow. This question, put in another way, asks whether we should irradiate only the malignant tissue and its immediate surroundings or a wide area of healthy tissue. Our experience has taught us that it is better to concentrate on the malignant area and a small area of healthy tissue only. We adopt as an important principle the production of a narrow beam of radiation in contrast with the field of our early apparatus and of some of those in use on the Continent. In some cases these fields are more accurately described as clouds of gamma rays rather than beams.

The first "bomb" was rapidly constructed to utilize an unlooked-for loan of a gram of radium. The principles and measurements were those of Regaud's cupola, which was selected after seeing those of Sluys, Mallet, Cheval, and Perussia, and analysing their fields as well as those of Regaud and Failla. Berven's apparatus at that time was small: little more, in fact, than a method of surface application of a few hundreds of milligrams. Our second apparatus was a modification permitting three positions of the four one-gram aggregates at the "corners" of a field no longer strictly square.

In the third apparatus the radium (which was supplied in twenty tubes) was arranged in a circle, the circumference of which could be altered at will by drawing the tubes radially towards the centre. In all these three types the protective casing was very thick, and the weight of lead precluded movement of the whole bomb on more than one axis. Elaborate apparatus was therefore necessary to bring the patient to the bomb in any desired position. Notwithstanding the mechanical perfection of this device two difficulties arose: (1) the time taken in application was greater than should be permitted if the personnel engaged was to be entirely safe; and (2) allowances for the comfort and unavoidable movements of a patient treated for one or more hours made strict accuracy of orientation and distance impossible.

Before this instrument had been in use three months it was decided that a different principle must be adopted: (1) the field must be small; (2) the apparatus containing the radium must be brought to the patient and not the

patient to the apparatus; (3) the skin-radium distance must be variable at will within certain limits; (4) the diminution of lead screenage necessary to permit of free movement of container must be compensated by increased distance between personnel and patient. A much smaller cupola was therefore constructed, pear-shaped, supported and counterbalanced on long lever arms mounted on a wheeled stand. The container could be moved on any axis, and the radium approximated or withdrawn by mechanical controls at a distance of five feet from the radium. This bomb housed the fifth gram of radium at our disposal, and, though faulty in some respects, led the way directly to the design of the current model.

Adverse comments have been levelled at the design of our four-gram container by those who had no personal experience of the working of such an apparatus. For the most part these strictures were the echoes of our own criticisms, which were explained in detail to those who inquired, and were anticipated by our fourth apparatus, which was the experimental form for a new four-gram model had the radium remained with us. It was used for two years as a one-gram machine, and is now superseded by the current model, which contains two grams of radium.

THE PRESENT MODEL

When a radioactive source of small dimensions is placed at the end of a channel in a block of lead the rays penetrate the metal bordering the opening, and a spreading effect is caused outside the region which is the prolongation of the channel; lateral regions of appreciable intensity are produced, and tend to destroy the beam-like character of the gamma rays. It has not, in fact, the character of a beam of light, such as would be produced if the radioactive source were a light source. The effect of spreading can be reduced if the channel has thick walls, but when lead alone is used the apparatus becomes inconveniently large. We have overcome this effect to an appreciable extent by making the lower end of the channel of gold, which, being more absorbent of gamma rays than lead, causes the field to fall off more rapidly at the boundary. By this means we succeeded in producing a remarkably good beam. Platinum would produce an even better result, but at greater cost. The external diameter of the bomb is approximately 14 cm., the internal diameter of the radiation channel 3.5 cm., while the gold mouth is 1 cm. thick and 3 cm. long. Complete details and dimensions will shortly appear in *Acta Radiologica*.

A second point of importance concerns protection. With regard to the patient there is no difficulty. No harm has resulted up to the present from irradiation of normal tissues of the patient by the weak parts of the field bordering the intense regions in our bombs. The concern of those in charge of massive radioactive sources is chiefly for those whose duty it is to apply the treatment. Our calculations of fields permissible in the neighbourhood of the apparatus were originally based on our experience of the effects observed on the skin, and especially from the Radiumhemmet, Stockholm. However, upon such data as we could collect from other sources, rules have now been laid down and published in a pamphlet issued by the Health Organization of the League

* Continuation of articles in the *British Medical Journal*, May 11th and August 3rd, 1929; February 8th and July 19th, 1930.

of Nations (Geneva, 1931) for guidance of radium workers and with a view to safeguarding them. Our subsequent measurements with a calibrated celluloid-walled electro-scope have shown that we are within the safe limits. It was very interesting and satisfactory to us to note that calculations made by the simple application of the inverse square law and the absorption of the apparatus gave results agreeing with the electro-scope. But whatever may be done to guarantee the safety of the workers the fact remains that the bomb is a weapon calling for careful handling. The chief factors in protection are ultimately distance and common sense.

APPARATUS AND METHOD OF APPLICATION

We have reduced the bomb to quite small dimensions and its weight to 38 lb. It is counterpoised over pulleys, and is able to rotate about an axis through its centre of gravity. It is thus easy to handle, and will stay in the position in which it is placed. The patient comes into the treatment room with a metal holder in the shape of a truncated cone of correct angle, fastened by elastic webbing already attached in such a position that when the bomb fits into it the radiation is directed to the lesion. Figs. 4 and 5 are intended to make clear the method of application. The patient sits on a couch, and is then swung into position under the bomb, and he can either push the apparatus into contact himself or it can be fixed by an attendant, who stands a few feet away and makes the necessary adjustments by means of a rod held in the hand. The actual fixing is at present made by means of an elastic band, which fastens the metal cone to the bomb and maintains the same relative position of bomb and patient, although the latter may make such slight movements as are to be expected from anyone stretched on a couch or sitting in a chair. The method of fastening is clearly capable of considerable variation, but it must be easy to work, and there should never be any need for the attendant to place his hand on the bomb, even though the amount of radiation through the upper half of it is very small.

CLINICAL APPLICATION OF MASS RADIATION

The object of mass radiation (or the use of a bomb) is to deliver to the tumour in all its parts gamma radiation of the highest practical intensity with the least possible damage to the skin and surrounding normal tissues, except the actual tumour bed. The advantages derived by the patient from such radiation are as follows:

1. No operative intervention is necessary, as in interstitial radiation.
2. Much more accurate treatment is possible than with plaques, collars, or other surface methods.
3. The depth intensity is greater.
4. The situation of the tumour is of less importance, as access to it is not so vital a factor, providing the quantity of radium available is sufficiently great.
5. The destructive effects on lymphocytes are less than with wide plaques of lesser intensity.

The efficacy of the method depends mainly upon the ratio between the quantity of radium and radium-tumour distance. From the experience gained in the use of the various bombs it can be postulated that for efficient mass or distance radiation it is necessary to make use of multiple ports of entry of small diameter, as it is thus possible to reduce the skin reaction to a minimum and increase the tumour dose to any desired quantity.

The selection of cases suitable for distance or mass radiation is dictated by practical considerations of the surface area to be treated, the radio-sensitivity of the growth, and the quantity of radium available. With the present apparatus and two grams of radium at a distance of 3 cm. erythema of the skin is obtained in six hours, and peeling in seven hours. Intermittent irradiation of

one hour per port of entry per day is found convenient and safe. Occasional periods of rest enable the total dose to be increased considerably. For the past year the cases treated consisted chiefly of pharyngeal cancer, malignant glands (neck, axillae, groin), metastases in the skeleton, mediastinal sarcoma, sarcoma of long bones, and selected cases of cancer of the breast. In a number of cases radium treatment and high voltage x -radiation were combined with great benefit to the patient.

The reactions in the skin and mucosa are similar to those obtained by other methods of radiation. With experience it is possible to control these reactions from a slight erythema to desquamation and selective radio-dermatitis. The degree of reaction permitted to occur varies with several clinical factors. An initial reaction occurs early in the treatment, and manifests itself by oedema and a primary erythema. The reaction proper occurs between the sixteenth and eighteenth days, with the methods at present used. The effects on the general health and on the blood picture are appreciably smaller than with the earlier machines. Radium-sickness at the Westminster Hospital Annexe has disappeared with improved technique. The blood counts show a progressive fall in the total number of white corpuscles, with a greater relative fall of lymphocytes. These changes, however, are far less marked with the present bomb than with extensive plaques—although the latter contain ten to twenty times less radium than the former—principally because less normal tissue is irradiated, and the total surface area treated is never extensive.

RESULTS OBTAINED FROM BOMB RADIATION

As we are not concerned in this paper with either statistical results or any other consideration except the possible value of mass radiation, it may be convenient to enumerate the results obtained, and contrast them with those of other methods of radium therapy.

1. Proved squamous-celled carcinoma of the buccal mucosa, floor of the mouth, palate, tonsil, lateral pharyngeal wall, pyriform fossa, and extensive carcinoma of the larynx have been made to disappear *in toto* with complete healing. They were undoubtedly selected cases; they represent so far early results; they are by no means a large proportion of the total cases treated; but they illustrate that squamous-celled carcinomata in these sites, irrespective of their clinical degree of operability, are amenable to a form of treatment not unpleasant to the patient, accurate, scientific, and safe both to the patient and to the personnel.

2. Cervical and inguinal glands secondary to squamous-celled carcinoma, fixed and inoperable, responded to treatment in certain cases. They are selected as illustrating a type of case which has proved a failure with collars, plaques, and needles, and which is by common consent "inoperable," even in the judgement of the most fearless and skilled operators.

3. Spheroidal-celled carcinoma of the breast, in selected cases, submitted to the bomb as unsuitable for surgery or needling, have led to disappearance of the primary growth and axillary glands. Inoperable tumours have retrogressed so satisfactorily as to permit surgical removal. This should not be taken as an indication that we consider the bomb to-day to be the treatment of choice for all, or even many, cases of cancer of the breast, and does not imply that surgery, or needling, or the two-stage irradiation by radium, are superseded; nor does it reflect on the results obtained recently by x -radiation alone in cancer of the breast. It is meant to convey only that the bomb has a useful place in the treatment of cancer of the breast. When and how to apply it requires judgement, knowledge of the disease, and appreciation of the likely failure or success of other methods.

4. Bone sarcomata, in the long bones and in the vertebrae, have been made to ossify, and have been seen to become replaced by apparently normal bone tissue for periods up to two and a half years, with relief of symptoms. Arrest of the disease locally, however, must not bring forth false hopes as to subsequent appearance of visceral metastasis.

It is therefore a legitimate conclusion that mass radiation at a distance by means of the so-called bomb is not only a useful weapon in the treatment of cancer, but a weapon so far unique in its possibilities and safe in its application. Besides the purely clinical use, the five bombs used at Westminster Hospital in the past four years have led to a much better appreciation of radium therapy. The bombs have been employed for the purpose of physical and biological research, and the following point to which we have paid attention is worthy of consideration.

From the observation of Spear and Grimmer (British Institute of Radiology, vol. vi, No. 67, p. 38) it would appear that, so far as inhibiting cell division is concerned, the most efficient way of using radium is to make use of a particular intensity, for, as a result of a series of experiments on tissue cultures *in vitro*, it is clear that biological response to gamma rays depends markedly on the intensity at which they are applied: if too great or too small an intensity is used the radiations are less effective. We have attempted to keep near to the useful intensity. The import of this observation is not yet completely clear, but we mention it here as a warning note to those who may be using large masses of radioactive material. For the natural tendency to produce the highest possible intensity with it may not necessarily be fruitful of good results.

This represents the progress we have made up to the present in the design and application of our apparatus. Daily use continually suggests improvements, and we have come to the conclusion that the best form of bomb would be one which contains the radium only during the period of treatment. This is certainly to be recommended in cases where 5 or 10 grams of radium are available. There is the obvious advantage that the patient can be placed carefully and accurately in position, since there is no haste on the part of the attendant to get out of the treatment room. There is also the advantage that the bomb can be much lighter, as almost the whole of the lead in its upper half can be removed; the latter is required to protect the attendants while making the final adjustment, and adds to the weight of the apparatus. It is possible to make up the active source in the form of a sphere, and to introduce it into the apparatus by rolling it down a tube. An alternative is to attach to the radioactive source a small motor-driven or pneumatic carrier, which would run into position when everything is prepared, and then run back again into the safe at the end of the exposure. Between treatments it would be kept in a lead safe, and when the patient was in position it would be projected into the bomb by an operation performed outside the room. In this way the attendants would be absolutely protected, and the efficiency of the treatment increased by the improvement in accuracy in placing the patient in the beam of gamma rays.

Daily personal experience over a long period of the difficulties and dangers attendant upon the accurate application of large masses of radium to the skin surface in all parts of the body, in such a way that the beam always traverses the tumour, has led, we hope, to some skill in the observance of the required "ritual": it has certainly led to increased respect for the dangerous possibilities inherent in its use by untrained or inexperienced people.

270 CASES OF FRACTURED SPINE RADIOLOGICALLY CONSIDERED*

BY

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RADIOLOGIST TO THE CARDIFF ROYAL INFIRMARY AND TO THE
PRINCE OF WALES HOSPITAL

(With Special Plate)

Until x rays made it possible to discover with certainty fractures of the spine the diagnosis of such injuries was usually confined to those cases in which there was an obvious injury to the spinal cord, with or without bony displacement. Since the introduction of efficient x -ray apparatus, and particularly since lateral views of the spine became available, it has become apparent that fractures of the spine are infinitely more common than was generally supposed. Such injuries are rare in ordinary occupations, and even in London dock areas they are comparatively scarce. In such localities they usually result from buffer injuries, or from falling into the holds of steamers, and there is very little to be found in surgical literature dealing with these cases.

But in coalfields such as those of South Wales, fractures of the spine are so common as to constitute the most frequent form of grave accident. When the occupation of the miner is considered, this is only a natural result. He works with the constant possibility of a fall of roof, sometimes amounting to tons, suddenly pinning him to the ground. The resulting injury varies according to the position that the man is in at the moment, whether standing, kneeling, or lying. If the fall comes on his head or neck, he is likely to sustain a fractured skull or a fractured cervical spine, and the result is, of course, often fatal at once. One reads of these cases almost daily, and in South Wales and Monmouthshire alone about 220 miners are killed outright each year. These unfortunate men never reach a hospital at all, but, from inquiry, I find that many of them have fracture-dislocation of the spine. If the man is in a stooping or kneeling position he may sustain a fracture of any part of the spine, a fractured pelvis, a fracture or dislocation of the hip, or a dislocation of spinal or sacro-iliac joints. Sometimes the original fall knocks the man flat, and, further falls occurring, he may sustain fractures of any of these parts.

MATERIAL CONSIDERED

Many of these men sustain serious spinal cord injury without fatal results, and some of them remain bed-ridden for many years. I have not included any of these in the series I am dealing with. The 270 cases of fracture referred to in this paper have all walked into my consulting room in the last five years. They have been sent to me in connexion with claims under the Compensation Act, and the vast majority of them have been miners referred by the South Wales and Monmouthshire Coal Owners' Indemnity Society. A few of them have been in dock accidents and other types of injury. I have not included fractures or dislocations of the cervical spine, of which I have had several, but have confined this investigation to the dorso-lumbar region, and dealt only with the period of five years. The investigations were carried out entirely from the Compensation Act point of view and not from that of surgical treatment. The length of history of these cases when seen by me varied from a few days to very many years. As many as 201 of them had a history of under five years.

TYPES OF FRACTURE

The majority of the fractures have been of the indirect variety—that is to say, the stone has fallen on the

* From a paper read before the Moynihan Chirurgical Club.

RADIUM TELETHERAPY: LATEST MODIFICATION OF WESTMINSTER HOSPITAL APPARATUS

FIG. 1.—First apparatus of the new type.

FIG. 2.—Showing details of latest apparatus.

FIG. 3.—The apparatus in use. The head is here held away to facilitate the observer's view, but in practice would be comfortably supported in a natural pose.

FIGS. 4 AND 5.—To make clear the method of selecting site and direction for treatment with subsequent rapid fixation of the radium container.