X-RAY AND RADIUM THERAPY FOR STUDENTS

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PREFACE

THIS short work is intended as a guide to the place of X-rays and radium in medical and surgical practice. It is compiled in part note form, and its concise format should make it of value to a wide field of students, postgraduate and undergraduate.

For the assistance of the undergraduate student of medicine desiring to further his knowledge of a subject often referred to by his teachers, but usually dismissed in a few words, there is added a short description of pathology and symptomatology, so that the picture of the disease treated is complete. The scope of radiotherapeutic technique can, in any case, be appreciated only in relation to the growth and spread of the disease under treatment. He need merely note the essential points in the technique and its relative importance.

Levels of dosage and a broad description of techniques have been added in small print, so that they may be consulted by those coming into closer contact with cases treated by radiotherapy.

The subjects considered are only those where radiotherapy has come to be an established method of treatment. A short work of this type cannot hope to cover every application of radiotherapy in medicine and surgery, particularly in the case of non-malignant disease. It was thought advisable, however, on the other hand, to describe certain types of malignant disease in whose treatment radiotherapy plays little part at present so that the importance of radiotherapy in malignant disease could be viewed in its proper perspective. Again, the treatment of skin infections is also omitted, as this comes in the province of dermatological practice, and there are many excellent works on the subject.

Nearly all references to theoretical physics have been omitted. Unfortunately, in many works such material is placed at the beginning of the book, and the unfortunate student, who begins his study with enthusiasm, finds that his path to the disease of interest is blocked with technical details, physical conceptions and mathematical formulæ. Such information can be found by the curious in many first-class works on the subjects. On the other hand, it was thought advisable to answer a few general questions at the beginning of the book. Their reading can be omitted by those more familiar with radiotherapeutic technique, or they can be consulted after reading a specific chapter, and will, it is hoped, answer the questions that may spring to the mind.

The percentage survival rates quoted following treatment are averages resulting from the mean of various statistical reports in this country. No two groups of statistical analyses ever coincide, and it was thought to be wiser to quote average figures rather than those quoted in any single report. The incidence rates are derived from the Registrar General's Review 1937–1946. Similarly, it has been my intention to describe only those principles of technique generally accepted in this country and abroad, and whose value has been generally agreed. There is wide divergence of technique from department to department, but certain principles are common to most. I have deliberately refrained from quoting particular authorities, or quoting my own views, so as to make the work as widely acceptable as possible.

In the writing of this work, I have widely consulted the premier work of reference by R. A. Willis, *Pathology of Tumours*, for pathological and other details. I hereby acknowledge my indebtedness. Of the major papers consulted, a bibliography is appended, so that for special reference the original paper can be read in full. Certain of the papers contain descriptions of what are now standard methods of treatment and classification. I apologise to the authors for any summarising I have carried out, in order to keep this work of reasonable size.

This work is an attempt to fill the gap in the literature which has prevented the student of medicine and surgery from assessing the benefits that may accrue from radiotherapy, as opposed to certain inherent limitations.

BASIL A. STOLL.

June 1952

FOREWORD

THIS book, as indicated by the author in the Preface, is intended as a help to undergraduate and postgraduate students, in appreciating the position of radiotherapy in medical and surgical practice. It is short and concise, and will prove an easy book of reference to what are, for the most part, the orthodox views on the place of radiotherapy and the conditions for which radiotherapy might reasonably be used.

The very nature of the book precludes the student from achieving any deep insight into radiotherapy. This can only come from experience and intimate study of a subject, which requires fundamental knowledge of a different type from that of general medicine, associated with prolonged clinical experience to provide the necessary authority for pronouncing on a patient. Provided that those who read and learn from this book, look upon it from this point of view (and do not abrogate to themselves the functions of a consultant in radiotherapy as a result of the acquaintance it gives them with the subject), the book will serve a very useful purpose and will have a good public.

The "question and answer" method for dealing briefly and pointedly with the physical and biological factors is novel. It should prove helpful, without overwhelming the reader with matter, which might seem to a doctor to be foreign to the usual scope of his work. The clinical conditions are dealt with systematically and in an orderly fashion, which should be useful for easy reference.

Radiotherapy is still a growing subject, in that methods and views have not yet reached maturity. Moreover, the new antibiotics and anæsthetics have increased the scope of surgery. There will be many specialists in surgery and radiotherapy, therefore, who will disagree about many points in the book, but who would also disagree with each other. Such a work has never previously been produced in radiotherapy, but there has been a growing demand which this book should help to satisfy.

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CHAPTER I

GENERAL PRINCIPLES OF RADIOTHERAPY

WHAT IS THE MODE OF ACTION OF RADIOTHERAPY ON TISSUES?

All methods of radiotherapy, whether using radioactive isotopes, X-rays emitted by a machine or gamma waves emitted by radium, depend essentially on the absorption of ionising radiations by the living tissues. Following absorption, there follow changes which may lead later to death or injury of these cells.

All cells, normal or abnormal, will absorb irradiation, but the degree of response will vary according to the histological type. This differential response is called the "*radiosensitivity*" of the cell type.

The more primitive cells of the human body, such as the reproductive cells and the lymphocytes of the blood, are more sensitive to irradiation than the more differentiated cells, such as nerve or muscle cells. Similarly, malignant cells, being of a more primitive nature, are on the whole *more sensitive to irradiation than the normal tissue*, and upon this fact is based the science of radiotherapy.

I. TUMOURS SUITABLE FOR RADIOTHERAPY

Each particular type of tumour has its own particular degree of radiosensitivity. For example, seminoma is a radiosensitive tumour and fibrosarcoma a radioresistant tumour.

It must be realised, however, that in the sense that the term is used by the majority of radiotherapists, the *radiosensitivity* of a tumour is not identical with its *radiocurability*. The former indicates a regression after radiotherapy which may be purely temporary, but it is the latter which decides the prognosis. Thus, embryoma of the kidney or medulloblastoma of the brain may regress very rapidly with small doses or irradiation, but both are very malignant tumours, with a tendency to recur and metastasise, and the prognosis is very unfavourable. It is the size of the *cancericidal* or tumour lethal dose which will decide the prognosis.

Thus, if the cancericidal dose necessary for any tumour is lower than the tolerance dose of the tissue around, i.e. of the tumour bed, then the tumour may be cured by radiotherapy (e.g. squamous cell carcinoma in accessible sites). If it is higher than the tissue tolerance dose (i.e. the tumour is a radioresistant type, such as a chondrosarcoma at any site), then curative radiotherapy has no place in its treatment.

The radiocurability depends therefore on:

(1) Radiosensitivity of the tumour.
(2) Radiotolerance of the site and tumour bed.
(3) Size of the tumour and its extensions.
(4) Accessibility of the tumour.

These factors are discussed separately as follows:

WHAT ARE EXAMPLES OF VARYING RADIOSENSITIVITY AMONG TUMOURS?

Very Sensitive.—Reticuloses, lymphoepithelioma, medulloblastoma, seminoma, embryoma of kidney, Ewing's tumour of bone.

Moderately Sensitive.—Squamous and basal cell carcinoma, spheroidal cell carcinoma.

Resistant (in general).—Fibrosarcoma, osteogenic sarcoma, malignant melanoma, adenocarcinoma, meningioma.

WHAT OTHER FACTORS INFLUENCE THE RADIO-SENSITIVITY OF A TUMOUR?

(*a*) *Histology.*—*Intermediate histological types*, such as basosquamous carcinoma and adenoacanthoma, are usually less sensitive than the pure types. Similarly, *heterogeneous* tissues, such as teratoma and mixed salivary tumour, are generally less sensitive than homogeneous tissues. Finally, with increasing *proportion of stromal tissue* (e.g. scirrhous carcinoma), the growth is generally less sensitive than with a highly cellular structure (e.g. Ewing's tumour of bone).

(*b*) *Gross Pathology.*—The papilliferous type of growth is more radiosensitive than the infiltrating type. The ulcerative type is usually not so sensitive because of secondary infection.

(*c*) *Localisation.*—Metastatic deposits in lymph glands are less sensitive than the primary growth. Epithelioma in skin is more radiosensitive than in mucous membrane.

(*d*) *Previous Irradiation.*—This always decreases the sensitivity of a lesion, and may be due to an induced radioresistance in the tumour cells which have survived a previous course of irradiation.

WHAT ARE THE LOCAL FACTORS IN THE SITE AND THE TUMOUR BED TOLERANCE?

(*a*) *Vascularity.*—The blood supply of a part determines to a great extent the tolerance to irradiation. A highly vascular part, such as the lip, will tolerate radiation well without tendency to necrosis. The presence of syphilitic endarteritis, or chronic lupus scarring, tends to radionecrosis.

Extremes of age and general debility also exert an adverse effect on the patient's tolerance to irradiation.

(*b*) *Site.*—The palms, soles, axillæ, groins, flexures and perineum all tolerate irradiation badly.

(*c*) *Previous Irradiation.*—This always adversely affects the skin and tissue tolerance, by decreasing the blood supply and inducing fibrosis.

(*d*) *Secondary Infection.*—Radiation lowers the resistance of tissues to sepsis, and the latter may tend to exacerbate after irradiation. In addition, the presence of secondary infection decreases the radio-tolerance of the stroma with a tendency to radionecrosis.

HOW DOES THE SIZE OF A TUMOUR AND ITS EXTENSIONS AFFECT RADIOCURABILITY?

This factor applies especially to deep-seated tumours, where external irradiation must pass through one or more portals of skin to reach the tumour.

The tolerance limit of the skin to radiation cannot be defined as a specific dose of irradiation, but (for any given quality of irradiation and time distribution) it varies with the size of the area irradiated. Thus, *the smaller the field the greater is the skin and tissue tolerance.* Therefore treatment areas must be kept as small as possible compatible with the effective treatment of the tumour and its extensions.

Using radium also, the smaller the volume irradiated the greater the tolerance.

Its Effect upon Technique.—(*a*) If an inaccessible tumour is more *radioresistant* and requires a high dose of irradiation, we must of necessity plan a homogeneous irradiation of as *small* an area as possible, in order to achieve the cancericidal dose within the tissue tolerance limits.

(*b*) If an inaccessible tumour is *radiosensitive*, it is commonly also very malignant and rapidly spreading. It is therefore necessary to irradiate a *large* volume of tissue, and high doses of irradiation are not possible within the tissue tolerance limits. As a result, cure is less likely. Similarly, if the lymphatic glands be involved, the radiocurability is prejudiced because of the large area that has to be irradiated.

WHY IS ACCESSIBILITY OF THE TUMOUR A MOST IMPORTANT FACTOR IN RADIOCURABILITY?

The best radiotherapeutic results are achieved with tumours of the skin, mouth and cervix uteri—all accessible lesions. In these cases, the size of the lesion and the variations of skin tolerance are not such decisive factors in limiting the tumour dose. Thus, for an accessible tumour to be cured, the tumour must be relatively radiosensitive and the tumour bed relatively tolerant to irradiation. For inaccessible growth, in addition to these requirements the tumour must be small and the patient's general condition able to withstand a debilitating treatment.

WHAT DETERMINES THE CHOICE OF METHOD—RADIUM OR X-RAYS?

Both X-rays and gamma-rays probably exert a similar biological action on tumour tissues, and the tissue changes resulting depend essentially on the amount of energy absorbed locally, whether from X-rays or radium. The shorter wave-lengths of gamma-rays from radium are, however, advantageous in the radiation of skin and bony tissues, these tissues being more tolerant to gamma-rays and less liable to develop necrosis with large doses.

Essentially, there are two main methods of irradiation:

(1) *External Irradiation.*—This is given either by an X-ray machine or a large radium source (teleradium). In either case, if the treatment is spread over 4–6 weeks, very similar skin and tumour reactions will result from equivalent doses.

In this method, irradiation is given intermittently (usually at daily intervals) at a high-dosage rate (treatment lasting only a few minutes).

By these means, doses as high as in the next method cannot be achieved, but large fields can be irradiated in a uniform fashion. The method, therefore, is especially indicated for:

(*a*) Tumours which are *radiosensitive* and rapidly spreading, so that *large fields* have to be irradiated.

(*b*) Tumours which are only moderately radiosensitive, but which are *inaccessible* to a local radium application. In this case, a localised area is treated to as high a dose as is possible within the limitations of the local tissue tolerance. The total dose, however, is limited because of the large volume of normal tissue outside the tumour area which must be traversed by the field of irradiation.

(2) *Local Radium.*—Radium sources can be applied to the skin, implanted in the tissues or inserted into body cavities, such as the mouth or cervix uteri.

In this method, irradiation is usually given continuously, generally for 5–10 days, and the dosage rate is low.

By this means a higher total dose than in the previous method is available, but only over a very localised area, the surrounding tissues being spared. Although the method of administration is very different from the previous method, the tumour and tissue reactions are essentially similar. The method is suitable, therefore, for the treatment of *accessible and localised growth*, which requires a high dosage because of its relatively *radioresistant* nature.

Thus, the final choice between radium and X-rays depends on the accessibility, size and radiosensitivity of the tumour it is required to treat.

II. X-RAY TREATMENT

HOW ARE X-RAYS PRODUCED?

X-rays are emitted when a tungsten target is bombarded by electrons emitted from a heated filament. The electrons pass through a vacuum tube, and are speeded up by the maintenance of a high potential across the tube.

HOW IS DOSAGE BY X-RAYS MEASURED?

Of necessity, a beam of X-rays must pass through a large volume of normal tissue in order to reach a deep-seated tumour. A dose of X-rays, therefore, must balance between the cancericidal dose and the tolerance dose of the connective tissue around (which will be responsible for repair later).

It is, of course, impossible to observe the reaction of the connective tissue of a patient to a course of irradiation, but it is assumed that its tolerance is the same as that of the skin; hence the reaction of the *skin* to irradiation is an indication of the safety limit beyond which a field must not be irradiated. Dosage of irradiation is measured in röntgens.

The Röntgen (*r*).—This unit is a physical concept, which is internationally accepted, of an amount of irradiation. It is defined as follows:

The röntgen shall be the quantity of X—or gamma—radiation such that the associated corpuscular emission per 0·001293 grams of air produces in air ions carrying 1 e.s.u. of quantity of electricity of either sign.

The definition is not important for the present discussion so long as the following principles are understood.

We can express the strength of an X-ray beam in röntgens, either at the skin level (*skin dose*) or at the level of the tumour (*tumour dose*). This difference in strength of the beam is due to the falling off in its intensity as it passes through the tissues. This is due both to the increased distance from the source and, more important still, due to the absorption of the rays in the tissue.

WHAT DETERMINES THE PENETRATING POWER OF A BEAM?

This quality depends on several factors, the most important in practice being the voltage across the X-ray tube. *The higher the kilo-voltage (or kV) the more penetrating the radiation*, and thus the less that will be absorbed in the superficial tissues.

From the previous discussion on skin and tissue tolerance, it becomes obvious that the more penetrating the irradiation, the greater the dose that can be achieved in a deep-seated tumour for a specific tolerance dose to the skin. The common range of high-voltage X-ray in this country is from 200–250 kV, but higher values than this are necessary in the effective treatment of very deeply seated lesions, such as those of the bladder, œsophagus, rectum or lung.

In these latter cases, 400–1,000 kV X-rays will yield a much higher dose at a depth relative to that on the skin. Rays of a similar wave-length to the gamma-rays of radium can be achieved by the use of voltages of about 1,500 kV.

On the other hand, 45–60 kV irradiation (low-voltage X-rays) has its value for superficial lesions and 100–140 kV (medium-voltage) irradiation for lesions just below the skin surface which can be cured without causing deep fibrosis.

Other factors which affect the penetrating power (and thus the depth dose) are the *filtration* of the beam through a metal filter, the *focal skin distance* (distance of the target or focus from the skin) and the *size of the field* treated. Increase of any of these factors will lead to an increase in depth dose ratio.

WHAT IS THE TIME FACTOR IN RADIOTHERAPY?

An additional factor that must be considered in addition to the size of the dose is the time factor.

The longer the fractionation of the total dose (i.e. the total time over which the dose is delivered), the greater is the skin and tissue tolerance. Unfortunately, at the same time, the tumour tolerance is also increased. Thus the total time of a course of treatment must always be specified in quoting a dose of irradiation. With regard to the interval between successive treatments within a course of X-rays, fractionation will tend to catch more cells in the radiosensitive mitotic phase if treatment is given daily or on alternate days than by longer intervals.

WHAT ARE THE MAIN TECHNIQUES OF X-RAY TREATMENT?

(*a*) *Single fields* are used for *accessible* lesions, either for curative or palliative purposes.

(*b*) *Simple arrangements of two fields* will yield a fairly homogeneous dosage for *palliative* or *prophylactic* treatment in inaccessible lesions.

(*c*) *Multiple small fields* directed at the lesion will yield the most homogeneous dosage and greatest dose at a depth for the *curative* treatment of inaccessible lesions.

(*d*) *Wide-field techniques* are used palliatively for the treatment of widespread disease, such as the reticuloses or multiple metastases.

HOW DOES CONSTITUTIONAL TOLERANCE AFFECT A COURSE OF TREATMENT?

Apart from the skin tolerance, there must be considered the constitutional tolerance of the patient. Irradiation, by causing the death of tissue, leads to the liberation of various toxic metabolic products in the body, apart from the destructive effects of the X-rays on the cellular elements of the blood. The constitutional effect is naturally greater, therefore, with larger size of fields irradiated and with greater penetrating power of the rays.

As a result, the *minimum* total quantity of irradiation must be used in order to avoid these effects, and thus all beams must be used to their best advantage. For example, a neoplasm of the mouth or pharynx should be irradiated through its area of lymphatic drainage in the neck; fields should be as small as possible, and beams should be planned to go through the shortest route to a tumour.

In addition, if a patient's general condition is poor, a palliative course of treatment to a low dose will be indicated. A radical course might kill the patient by its constitutional reaction, before the local neoplasm might disappear.

HOW IS A COURSE OF X-RAY TREATMENT PLANNED?

If the previous points as to tumour dosage and skin tolerance are understood, the following scheme of planning an X-ray treatment follows logically.

(*a*) Decide the *tumour dose* and *total time* necessary for the fractionation. This depends essentially on the radiosensitivity of the lesion, e.g. 2,000 *r* (or röntgens) in 2 weeks for a sensitive tumour like lymphadenoma, or 5,000 *r* in 5 weeks for a more radioresistant tumour like spheroidal cell carcinoma.

(*b*) Decide the *size* of the tumour-bearing area to be treated. This depends on the size of the primary growth, its lymphatic extensions, etc.

(*c*) With the preceding prescription, decide what size, number and distribution of fields are necessary to achieve the required dosage in the tumour, without exceeding the tolerance limits of the skin fields through which the radiation must pass. In addition, homogeneity of radiation is essential both to avoid local overdosage (and necrosis) or underdosage (and recurrence of growth).

Thus in the following discussions, treatment doses recommended are tumour doses. The specific size and number of fields are decided for each case separately, bearing in mind that the tolerance limits for those fields must not be exceeded.

WHAT ARE THE INDICATIONS FOR X-RAY THERAPY?

These can be broadly classified as follows:

(1) *Primary Radical.*—For tumours capable of cure by radiotherapy, giving better results by radiotherapy than by surgery, or tumours in patients unsuitable for surgery.

(2) *Palliative.*—To cause partial regression of advanced growths or metastases. To relieve pain or ulceration from primary or secondary advanced growths.

(3) *Postoperative.*—Either "prophylactically" to sterilise neoplastic cells set free at operation or when removal of a tumour is incomplete.

(4) *Preoperative.*—To decrease the size of a tumour and make operation easier or to decrease the viability of the tumour cells so that metastasis at operation is less likely.

Certain principles must be established in this respect:

Postoperative prophylactic irradiation as a routine is indicated only in cases where radiotherapy is not an effective alternative radical treatment to surgery. Thus, in the case of bladder carcinoma, if postoperative irradiation is requested by the surgeon it indicates that the choice of surgery in the first place was a mistake. On the other hand, where radiotherapy is not a feasible curative form of primary treatment, its addition to surgery may be capable of controlling a few stray neoplastic cells. This may be achieved both by its direct action on the cells and by its indirect action on the stroma, whereas it would not be successful in controlling a large mass of tumour tissue. This is the case, for example, in carcinoma of the breast, ovary, testis, thyroid, uterine body and kidney.

Palliative irradiation should be undertaken only in the presence of troublesome symptoms, or to prevent such symptoms arising later. Dosage should not be taken to radical levels, because severe skin and mucosal reactions, with their attendant discomfort, are not justified. In the absence of disturbing symptoms, e.g. in some cases of advanced bronchial carcinoma, where there is no hope of cure, there is no indication for radiotherapeutic treatment.

A difficult problem is the case of very advanced bladder or uterine carcinoma where bleeding is a prominent symptom and where pain is absent. Although palliative irradiation will cause temporary control of bleeding, the patient is saved from death from hæmorrhage in order to bear the burden, in many cases, of severe pain later.

III. RADIUM TREATMENT

HOW DOES RADIUM ACT?

The element radium has a natural decay rate, so that half the atoms in any specimen decay in approximately 1,700 years. At various stages in the process of decay, the element emits alpha- and beta-particles and gamma-rays. The alpha-particles have the structure of the nucleus of helium atoms, and are the least penetrating of the emissions, being absorbed even by a sheet of paper. The beta-particles consist of electrons and are more penetrating, requiring 0·5 mm. of platinum (or its equivalent) for their absorption. The gamma-rays are electro-magnetic waves, and are the most penetrating of the emissions.

Radium-rays are "filtered" in order to obtain pure gamma-rays, the most penetrating of all. Thus, the usual metal cover of a radium needle, 0·5 mm. of platinum or its equivalent, will absorb 99·9 per cent. of the beta-rays, and of course all the alpha-rays. The presence of the poorly penetrating beta-rays would cause intense necrosis in the immediate neighbourhood of radium implanted in a tumour, but would have no effect on the outlying portion of the tumour.

Radon gas consists of radium emanation which is radioactive like the parent salt, but decays much more rapidly, so that its "half-life" is only 3·85 days.

HOW IS DOSAGE BY RADIUM MEASURED?

The quantity of radiation emitted by radium can be stated in terms of röntgens as follows:

"1 mgm. of radium filtered by 0·5 mm. of platinum will yield 8·4 röntgens per hour at 1 cm. distance from it." At increasing distance the dose falls off very rapidly.

The expression of a dose of irradiation by radium, in the form of milligram hours, is not significant. It indicates only the quantity of radiating power available at the source, and not its distribution or the radiation absorbed at any particular point in a tumour. In addition, although the two methods will yield an equal quantity of milligram hours, a very different biological effect will result from a small radium source over a long period as from a large radium source over a short period.

The time and volume factors in tissue and tumour tolerance apply in exactly the same way as for X-rays.

WHAT ARE THE MAIN METHODS OF RADIUM TECHNIQUE?

Radium can be utilised in the following ways:

(*a*) *Interstitial Radium*.—Radium needles are implanted into and around a tumour, irradiation thus being limited to the tumour and its bed. The method is available for accessible lesions, although implantation can be carried out at open operation for inaccessible lesions, such as the bladder (when radon "seeds" are generally preferred, as they can be left in permanently). Homogeneous dosage throughout a tumour is essential in all forms of radiotherapy, but especially so in radium implants. Due to the very high local dosage and very rapid fall off around, there is a danger that one portion of the tumour may be overdosed, leading to necrosis, and another part underdosed, leading to recurrence of growth.

Homogeneous and adequate irradiation will be achieved if the rules laid down by Paterson and Parker for the calculation of the quantity of radium necessary, and its distribution, are followed.

(*b*) *Intracavitary*.—Radium sources can be distributed in a container and inserted, for example, in the cervix uteri, vagina, mouth or other hollow viscus. By this method it is difficult to achieve as homogeneous a distribution of radiation as by the previous method; distribution being limited by the anatomy of the part. High localised dosage may be achieved, but the fall off in dose even at short distances is very high.

The advantage of this method over interstitial radium is, however, that the dosage may be fractionated at will, e.g. in the mouth for purposes of feeding, and also that no anæsthetic is necessary for its application. The choice is further discussed later under oral cancer.

(*c*) *Surface Radium*.—Radium tubes may be mounted on a moulded base and applied to a superficial tumour. Homogeneous irradiation of a tumour and its bed is possible if the rules of Paterson and Parker for radium distribution are observed.

The advantage of the method over external irradiation is that curved or irregular surfaces can be homogeneously irradiated by this method. On the other hand, there is little penetrating power, and only an accessible and superficial tumour can be so treated.

(*d*) *Teleradium*.—Radium tubes may be set in a container in quantities up to 10 grams of radium, in order to emit a sharply defined beam of gamma-rays similar to an X-ray beam. Due to the small quantities of radium available, only small fields can be treated, and then only lesions not at a great depth. The use of large radioactive cobalt sources promises advance in this direction.

WHAT DETERMINES THE CHOICE BETWEEN X-RAYS AND TELERADIUM?

In view of the shorter wave-length of gamma waves, it might be expected that teleradium would produce a more penetrating beam than 250 kV X-rays, and thus give the higher depth doses. In actual fact, due to the small quantities of radium available, a relatively short radium skin distance must be used if sufficient radiation is to be absorbed in a convenient time. This factor militates against high depth doses for physical reasons.

X-rays have the advantage over teleradium in that varying shapes and sizes of applicator can be used for each tube, and, in addition, the penetrating power of the beam can be varied according to the depth of the lesion, by altering the kilovoltage, filtration, or focal skin distance. Finally, the rapid output of an X-ray tube is less tiring to the patient.

As stated before, however, there is definite evidence that both skin and bone appear to show more tolerance to radiation by radium than by X-rays.

WHAT ARE THE ADVANTAGES OF SUPERVOLTAGE?

In recent years, voltages up to 2,000 kV have become available in X-ray machines, and up to 20 million electron volts in particle accelerating machines, such as the betatron and linear accelerator. The advantages are that much higher doses at a depth can be achieved within the limits of skin tolerance dosage, due to the greater penetration of the beam. In fact, with the highest energy machines, the dose at several centimetres below the surface of any one field may be 2 or 3 times the dose at the skin.

The skin thus ceases to be the limiting factor in external irradiation, but, in effect, mucosal changes and deep fibrosis limit the dosage. Thus, in treating the rectum, stricture of the ureters and perirectal fibrosis are serious complications, and in treatment of the œsophagus, lung fibrosis is very marked. Nevertheless, the advantages of supervoltage include relatively less severe blood and constitutional changes and also less radionecrosis of bone, associated also with the advantage of less severe skin reactions and less complex beam arrangements.

There is no evidence of an intrinsically superior biological effect of supervoltage on tumour tissue.

IV. RADIATION EFFECTS IN THERAPY

WHAT IS THE SKIN REACTION TO IRRADIATION?

This is of three degrees:

(*a*) *First Degree.*—This is the usual reaction to therapeutic dosage and consists of a bright red erythema of the skin appearing after 2 to 3 weeks. There is associated temporary epilation. The erythema is maximal after 4 or 5 weeks, and is followed by dry desquamation. A degree of pigmentation often persists for years. A white fibrinous exudate associated with erythema is the corresponding reaction of mucosa.

(*b*) *Second Degree.*—This is the reaction to therapeutic dosage taken to full skin tolerance, and consists of a dark-red erythema and skin œdema appearing after 2 to 3 weeks. Destruction of the epidermis leads to blistering of the skin after 4 or 5 weeks, and there is associated permanent epilation and desquamation with destruction of the sebaceous and sweat glands. The skin heals in 2 to 3 months, but permanent skin atrophy, pigmentation and telangiectasia commonly develop after 6 to 9 months. The last is due to obliteration of the blood vessels in the dermis by fibrosis.

(*c*) *Third Degree.*—This is the skin reaction to relative overdosage, and involves destruction of the dermis and the development of a painful necrotic ulcer. Healing, if it occurs, is slow, due to the endarteritis around.

The ulcer has an indurated edge and base and a grey sloughing floor, so that it may be difficult to differentiate from recurrent neoplasm. A similar ulcer occurs on mucous surfaces.

WHAT IS THE CAUSE OF NECROSIS?

Necrosis occurring immediately after treatment is due to absolute overdosage by irradiation (due to error), or due to low tolerance of the tissues in an individual. The latter is the common cause, and is found in special sites (e.g. soles, palms and perineum), or may be associated with relative avascularity (e.g. presence of syphilis or previous irradiation), or develops in the presence of infection. The presence of immediately adjacent bone or cartilage tissue to a lesion tends to the development of bony or cartilaginous necrosis.

Necrosis of the skin or other tissue may occur months or years after the original irradiation if it was carried to high dosage. The process may be initiated by slight trauma or infection. Extraction of a tooth may lead, for example, to osteomyelitis in an irradiated jaw.

It must be emphasised that the margin between normal tissue and