

RADIOISOTOPES IN THE TREATMENT OF CANCER

In the treatment of cancer, radiation can be administered to the malignant tissues in several different ways: for example, needles of radium or cobalt-60 can be implanted directly into the tumor, or (in a rather limited number of cases) a radioisotope in liquid form (e.g. gold-198) can be injected, knowing that it is likely to concentrate in a specific tissue. However, by far the most important therapeutic technique is teletherapy (or beam therapy) in which the source of radiation remains outside the body and the beam of radiation is directed at the tumor through the overlying tissue. The source of radiation may be an X-ray tube, a "supervoltage" machine such as a betatron or a linear accelerator, or a radioisotope which emits high energy gamma-rays. The two isotopes commonly used for this purpose are cobalt-60 and cesium-137.

Radiation treatment of malignant growths is not, of course, a novel procedure; both radium implants and X-rays generated at medium voltages (up to 250 kV) have been used all over the world for many years. However, large scale production of radioisotopes in atomic reactors has made radiotherapy available for the first time in less developed areas of the world. Moreover, the treatment has been simplified and, in many cases, made more effective.

Radium Teletherapy Units

The early teletherapy units, dating back to the 1920's, contained radium, a naturally occurring radioactive element. These "radium bombs" were developed, for example, in the Memorial Hospital, New York, the Paris Radium Institute, Radiumhemmet in Stockholm and Westminster Hospital, London. The designers and users of radium teletherapy units were faced with a cruel dilemma: only a few grams of radium were available for each unit. Ten grams was considered a large unit, yet this is equivalent to only about 6 curies of cobalt-60 or about 24 curies of cesium-137. In contrast, a modern cobalt unit commonly holds between 1 000 and 5 000 curies. It was not merely a question of cost, but of availability, since larger amounts of radium simply did not exist. In order, therefore, to provide a reasonable intensity of radiation at the tumor, radium units had to be used with the source quite close to the surface of the patient, usually 5 to 10 cm. However, the intensity of radiation is only one factor in the problem, and it is easily shown that, in order to treat deep-seated malignancies effectively, the source must be as far away from the patient as possible - in practice 50 to 100 cm. - always bearing in mind that the radiation intensity decreases in proportion to the square of the distance. Radium units could thus be used only for treating tissues quite close to the surface; and, in spite of the short working distance, exposure times of 30 minutes or longer for each irradiation were common.

Advantages of Modern Teletherapy Units

The availability of very large amounts of cobalt-60 and cesium-137 through atomic reactors has completely transformed the situation. As already indicated, sources equivalent to hundreds, or even thousands, of grams of radium are commonplace. Indeed a single multi-kilocurie unit may contain radioactive material equivalent to more than the total amount of radium existing in the world. With such large sources it is possible to work at the required distance (50 to 100 cm.) and yet retain a sufficient intensity of radiation at the tumor to necessitate exposures of only a few minutes at each treatment session.

Although the modern teletherapy unit must be regarded as a development of the radium bomb, it is more usual nowadays to compare such units with 250 kV X-ray sets and with supervoltage X-ray equipment. As compared with a so-called conventional X-ray set, operating at 200-250 kV, an isotope teletherapy unit has several advantages, of which two deserve special mention: the isotope unit emits radiation of higher energy, and it is much simpler in engineering construction.

The gamma rays emitted by cobalt-60 are virtually mono-energetic, of an average energy 1.25 MeV (million electron volts). Those from cesium-137 have an energy 0.66 MeV. In comparison, the average energy of the X-rays from a 250 kV set is about 0.13 MeV, i.e. only one-tenth of the cobalt energy. The higher energy of the cobalt gamma rays leads to several advantages, the chief of which is the greater penetrating power of the beam. Radiation thus reaches deep-lying tissue with less absorption in, and hence damage to, overlying tissue. This fact also allows some simplification in treatment technique. Furthermore, because of an effect known as "build up", the higher energy beam spares the skin, so that the patient avoids the painful "sunburn" (or worse) which is frequently a feature of conventional X-ray therapy. Thus the treatment is in many ways easier and more comfortable for the patient.

The second main advantage of a cobalt unit - its mechanical simplicity - cannot be over-emphasized. In the less developed countries this factor is almost certainly decisive. An X-ray set is a highly complex piece of electrical machinery in which many components - the transformer, the high-tension cables, the X-ray tube, to name only three - can and do go wrong from time to time. In contrast, a cobalt unit has practically nothing that could break down. Once installed, an isotopic teletherapy unit should need little or no servicing.

It remains only to compare an isotopic teletherapy unit with a "supervoltage" machine, such as

a betatron or a linear accelerator, from which high energy X-rays (or alternatively streams of electrons or other particles) may be obtained. In relation to such machines, the cobalt unit can no longer claim an advantage in terms of the energy of its radiation; in fact, many accelerators produce X-rays of higher energy than the rays from cobalt-60. On the other hand, the greater mechanical simplicity of the isotope units remains, since high energy accelerators are even more complex than conventional X-ray sets. The accelerator is thus suitable - at least at the present time - only for advanced centers in which experienced physicists and engineers are permanently available.

Why Co-60 and Cs-137?

An isotopic source, of course, has its disadvantages as well. Unlike an X-ray set or an accelerator, the radiation from an isotopic unit cannot be turned off, so it is necessary to surround the radioactive source with a massive container of lead or other heavy material. This container is provided with an opening of variable dimensions (the collimator) through which the working beam emerges, the opening being closed by a shutter when no radiation is required. The design of an isotopic teletherapy unit is essentially a question of the container, the shutter and the collimator.

Another disadvantage of an isotopic source is that its activity decreases continuously owing to radioactive decay. In due course the intensity of the radiation emitted falls to such an extent that the source has to be replaced altogether. Obviously the isotope chosen should have as low a rate of decay as possible so that replacement of the source is needed only at long intervals. Cobalt-60 has a "half-life" of 5.3 years, while the "half-life" of cesium-137 is about 30 years.

The main requirements of an isotope for use in teletherapy may thus be summarized as follows: (i) it must have a long half-life; (ii) it must emit high energy gamma rays; (iii) it must be available in large quantities; and (iv) it must be available with high "specific activity" so that radioactive material emitting a very high intensity of radiation can be concentrated in a source of small physical dimensions. For practical purposes, Co-60 and Cs-137 are the only isotopes which satisfy these requirements to a sufficient extent.

The Growth of Radioisotope Teletherapy Units

The first two cobalt teletherapy units were installed in Canada in 1951, at the Saskatoon Cancer Clinic and the Victoria Hospital, London, Ontario. Ten years later, there are well over 1 000 isotopic teletherapy units in different parts of the world. While, of course, the majority of these units are to be found in the technically advanced countries, some units have already been installed in a number of the less developed countries, and there is considerable scope for further expansion.

At present, teletherapy units are manufactured in 12 countries: Canada, Czechoslovakia, France, Germany, Hungary, Italy, Japan, the Netherlands, Sweden, United Kingdom, USA and USSR. There are more than 50 different designs of cobalt units, and at least 16 different models of cesium units.

Role of IAEA

IAEA has not remained a mere passive observer of these developments. The Agency has been active both in assisting the establishment of new installations and in trying to ensure that the best use is made of existing installations. The Agency has carried out these tasks by collecting and disseminating useful data, by enabling urgent problems relating to teletherapy to be discussed - and followed up - on an international basis, and by providing direct assistance to centers in the less developed countries.

When a new teletherapy installation is contemplated it is natural to ask: what units are available, what are their distinctive features and how much do they cost? These questions were answered in the "International Directory of Radioisotope Teletherapy Equipment" which the Agency prepared and published in 1959. Once a unit is installed, the task is to operate it successfully in the treatment of patients. This involves both medical and physical problems, and the Agency has concentrated its efforts on the latter.

Dr. K.C. Tsien (left), a member of the Agency's scientific staff, who has visited several Member States in connection with the use of large radiation sources for medical purposes, and Dr. Silverio, a Philippine radiotherapist, in front of a cobalt-60 teletherapy unit at the North General Hospital, Manila



Many of the problems come under the general heading of "dosimetry", i.e. the determination of the "dose" of radiation delivered at each point in the tissues of a patient, under various conditions of irradiation.

The Agency's Dosimetric Program

One of the most important items of dosimetric data is the isodose chart, a kind of contour map which shows how the dose of radiation varies from point to point under stated conditions. Hundreds of such charts have been measured or computed in advanced radiotherapy institutes, but the task is beyond the capacity of the majority of centers. Obviously there is a need for this kind of material to be collected, systematized, catalogued and redistributed on a world wide scale. The problem was examined in detail by an international panel of experts which met in Vienna in November 1960. Prior to this meeting a standard questionnaire was sent (through the co-operation of several national associations of medical physicists) to a large number of radiotherapy centers in many countries. Not only the answers to the questionnaire, but examples of isodose charts from different centers were brought to the Vienna meeting by the participants. The recommendations of the panel have recently been published by the Agency under the title "Therapeutic Dose Distributions with High Energy Radiation". It was suggested that the Agency should publish atlases of isodose charts under 3 main divisions, viz: single fields, multiple fields and moving beams. The preparation of these publications is now well advanced, material having been collected from all over the world, and they should be available in 1962. Associated with the atlases there is to be an "International Catalogue of Single Field Isodose Charts" and provisional copies of this have already been sent out, for comment and correction, to the contributing radiotherapy centers.

The isodose chart is not, however, the only item of dosimetric data which calls for discussion, agreement and action on a wide scale. Many other problems in clinical dosimetry, from terminology to the effect of body composition on the dose distribution, still await international recommendations. Some of these problems were considered by a Study Group on the "Standardization of Radiological Dosimetry for Radiation Beams" which met in April 1961 and was sponsored jointly by IAEA, WHO and ICRU (International Commission on Radiological Units and Measurements).

Another important and fundamental dosimetric problem, now being studied internationally under

Agency sponsorship, is the measurement of the output of radiation from isotopic sources intended for teletherapy. A small group met in Vienna in December 1961 to consider the possibility of international standardization in this field.

Other Aspects of Teletherapy

Dosimetry is only one of many problems in teletherapy. There are many other questions of a more general nature, including those of organization, staff (medical, physical and auxiliary), training, the selection of suitable equipment and radiation protection. These were some of the problems considered by an international Study Group on the "Use of Radioisotope Teletherapy Units and Supervoltage Radiation in Radiotherapy" which met in Vienna in August 1959. It was convened jointly by the Agency and the World Health Organization. The report of this group, which was published in 1960, not only reviewed the existing situation but provided a practical guide both for practising radiotherapists and radiation physicists and for those considering the establishment of radiotherapy centers. The recommendations of this group have been widely reported and acted upon. Indeed, much of the subsequent activity of the Agency in the dosimetric field, already detailed in this article, stemmed from suggestions made by the 1959 group. According to present plans, the work of this group is to be followed up and extended, with special reference to the needs of the less developed countries, by a Study Group which is to meet in the autumn of 1962.

Direct Assistance

Apart from the general studies described above, an expert from the IAEA Secretariat has visited several Member States, at their request, to assist in the installation or operation of isotopic teletherapy units. So far, this has been done in five countries: China, Greece, Iran, Philippines and Thailand. In addition, the services of a few outside experts have been provided to Member States under the Agency's technical assistance program.

At the last session of the IAEA General Conference, the Czechoslovak delegate announced that his Government was ready to contribute a cobalt-60 unit, with all accessories, for a technical assistance project in one of the developing countries. Arrangements would also be made for the training of two persons in the use of such equipment in one of the medical institutes of Czechoslovakia.