DEVELOPMENT OF

THE MEDICAL USE OF IONIZING RADIATION

Report by the Director-General

CONTENTS

1. INTRODUCTION .................................................. 3

2. DEVELOPMENT AND NEED FOR RADIATION MEDICINE ................. 3

   2.1 Diagnostic radiology ........................................ 4
   2.2 Radiotherapy ............................................. 4
   2.3 Nuclear medicine ........................................ 5
   2.4 Medical physics .......................................... 5

3. HEALTH RISKS FROM IONIZING RADIATION ............................ 5

   3.1 Radiation effects ........................................ 5
   3.2 Risk evaluation for personnel ............................. 6
   3.3 Risk evaluation for patients in diagnostic radiology ....... 6

4. FACTORS INFLUENCING RADIATION QUALITY AND RADIATION EXPOSURE .. 7

   4.1 Frequency of radiation exposure ........................... 7
   4.2 Technical factors in diagnostic radiology ................. 8
   4.3 Technical factors in radiotherapy ......................... 8
   4.4 Technical factors in nuclear medicine .................... 8
   4.5 Training and experience in radiation medicine ........... 9
   4.6 Organization in radiation medicine ...................... 9

5. PRESENT STAGE OF DEVELOPMENT OF RADIATION MEDICINE .......... 9

   5.1 Staff available to practise radiation medicine ............ 9
   5.2 Radiological equipment and facilities .................... 9
   5.3 Frequency of applications ................................ 10
   5.4 Forecasts for the future .................................. 10

6. THE OPTIMUM USE OF RADIATION MEDICINE ........................ 10

   6.1 Radiation medicine in the health service context .......... 11
   6.2 Priorities within radiation medicine ...................... 11
   6.3 Training and education of staff .......................... 11
   6.4 Methods applied and equipment used ....................... 12
   6.5 Frequency of application ................................ 12
   6.6 Radiation protection services ............................ 12
7. WHO PROGRAMME IN RADIATION HEALTH

7.1 Direct assistance to governments

7.2 Technological promotion and support

7.3 Designation of reference centres

7.4 Research

7.5 Coordination with other organizations
1. INTRODUCTION

1.1 In resolution WHA24.31 the Twenty-fourth World Health Assembly requested the Director-General:

(i) To study the question of the optimum use of ionizing radiation in medicine and the risks to health induced by the excessive or improper use of radiation;

(ii) To draw up a programme of activities based on the rationalization of the medical use of ionizing radiation and on the improvement of related diagnostic and therapeutic techniques and equipment, including clinical dosimetry and radiological protection; and

(iii) To report to the Twenty-fifth World Health Assembly on the results of his study and on this programme of activities.

1.2 To fulfil this request field assignment reports and other WHO and IAEA reports have been evaluated, in addition to as yet unpublished scientific information available at headquarters, information requested from countries through the regional offices and current scientific literature, including the publications of different national radiation protection services, the International Commission on Radiological Protection (ICRP) and, particularly, the reports of the United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR). The resolution was also considered by a Joint IAEA/WHO Expert Committee on the Medical Uses of Ionizing Radiation and Radioisotopes.1

1.3 This report contains:

(i) background information on radiation medicine, its benefits and risks;

(ii) information on the present stage of development of radiation medicine in developed and developing countries and forecasts for the future;

(iii) an estimate of the possibility of making the optimum use of ionizing radiation, in relation to effectiveness, benefit/risk and benefit/cost; and

(iv) a review of WHO programme activities.

For the sake of brevity, only limited quantitative material is included.

2. DEVELOPMENT OF AND NEED FOR RADIATION MEDICINE

X-rays were first used for diagnosis 87 years ago, and are now used to elucidate the structure and function of human and animal tissues and organs, on the basis of differences in density and atomic composition of tissues and body cavities and with the help of contrast media.

Shortly afterwards radiation began to be used on an empirical basis in the treatment of inflammatory, degenerative and neoplastic diseases. Radium and, later on, artificially produced radionuclides such as cobalt-60, cesium-137, and strontium-90, in sealed or unsealed form, were introduced. Nuclear medicine developed after the Second World War.
2.1 Diagnostic radiology

Diagnostic radiology may be divided into:

(a) basic radiodiagnostic examinations, comprising approximately two-thirds of all examinations undertaken in any radiodiagnostic department;

(b) advanced examinations, comprising those of the gastrointestinal tract; and

(c) special examinations, e.g. angiography.

It is estimated that about a third to a half of crucial medical decisions are dependent on X-ray diagnosis, and the early diagnosis of some diseases depends completely on X-ray examination. Chest examinations amount to 50 per cent, or more of the total number of X-ray examinations, and basic radiodiagnostic examinations to about 80 per cent. of all examinations in most places where advanced radiodiagnosis is also available. Special examinations, on the other hand, do not comprise more than 1-2 per cent. Where resources are limited, attention has to be focused on the development first of basic and later of advanced radiology; special examinations can be performed only in large teaching hospitals or special clinics as long as the medical services of a given country are not fully developed.

2.2 Radiotherapy

The methodology, techniques and forms of radiotherapy have developed greatly, and a large variety of radiations are now available. X-ray apparatus for energies ranging from 10 kV for skin therapy to 400 kV for conventional deep therapy has been widely replaced by telecurie therapy with cobalt-60 or cesium-137, with advantages in dose distribution and specific absorption. Linear accelerators and betatrons with energies up to 45 MeV have become available for the production and therapeutic use of extremely penetrating gamma rays and for fast electrons. Other types of radiation, such as protons, neutrons, and pi-mesons are being employed for therapeutic purposes, although at present this is at the research stage.

The interstitial and intracavitary application of small radium sources has proved effective, particularly in the treatment of cancer of the female genital tract, and is still one of the most widely used methods. However, radium may be replaced by other radioisotopes, making use of the "after-loading" technique, which again broadens the spectrum of dose distributions available for individual cases and in addition reduces remarkably the radiation exposure of the staff involved.

The availability of artificially produced radioisotopes has made it possible to use radioactive drugs which either enter into metabolism (e.g. iodine in the thyroid) or follow physiological routes of distribution (e.g. colloidal gold in the lymphatic system). These radiotherapeutic measures, although they have generally not proved as effective as expected, are of value for some diseases.

Apart from technical advances, the radiobiological background has been further explored and both the theoretical background and the practical application of radiotherapy have benefited. Radiotherapy is now an essential part of cancer therapy.

The practice of modern radiotherapy makes it desirable that radiotherapists should be familiar with and have access to the whole range of methods available. The Joint IAEA/WHO Expert Committee did not recommend different levels of radiotherapy as it did for diagnostic radiology.
2.3 Nuclear medicine

The large number of artificially produced radionuclides and the extreme sensitivity of the methods devised to detect the radiation emitted are the basis of the specialty of nuclear medicine, which has become established during the last three decades. If a chemical compound is labelled with suitable radioactive atoms it can be followed through the body and the pattern of its distribution and its participation in metabolic processes can be traced. The radioactivity can be measured either outside the body or from samples of body fluids or tissues.

During the last few years there has been an increased use of short-lived radioisotopes extracted from generators or produced in cyclotrons or medical research atomic reactors. They enable many diagnostic procedures to be performed with little exposure of the patient to radiation.

The Joint WHO/IAEA Expert Committee considered that nuclear medicine should be practised at different levels and in departments of different size, according to local needs. The integration of services at national level was considered desirable, however, in order to make the optimum use of facilities and manpower.

2.4 Medical physics

Whereas in the early days of radiology the physical problems, including dosimetry, were mostly dealt with by the radiologist himself, the services of a suitable and specially trained physicist are now indispensable because of the complexity of methods and physical problems in modern radiation medicine. Medical physics is a separate specialty concerned with aid in the clinical applications of radiation medicine, research and development of new and better methodologies, and the introduction of new types of radiation into medical use. It is thus an integral part of radiation medicine.

One of the important tasks of the medical physicist is dosimetry. Radiation medicine, and particularly radiotherapy, require the highest possible precision and accuracy of dose. Errors can easily result when the dosimeter is not accurately calibrated or properly used. Consequently calibration facilities for dosimeters, particularly for radiotherapy but also for radiation protection in all branches of radiation medicine, are of vital importance.

3. HEALTH RISKS FROM IONIZING RADIATION

Whereas the main biological effect of ionizing radiation in sufficient dosage - the destruction of cells and tissues - is used for therapeutic purposes, this effect is not desired in the other branches of radiation medicine. However, most of the radiation applied in radiodiagnosis and nuclear medicine is unavoidably absorbed within the body and may create undesirable side effects. The problem of side effects, of course, is common to many therapeutic and diagnostic procedures. Three types of biological side effects occur, with different characteristics and of different importance: (a) somatic; (b) late somatic; and (c) genetic.

3.1 Radiation effects

Somatic effects occur relatively soon after irradiation, with latency periods of a few days up to several months, depending on the radiation dose received and the organ or tissue affected. The severity of the effect itself is dose-dependent and may range, for example, from a light transient erythema of the skin after local irradiation with about 200 roentgens to a heavy erythema with subsequent pigmentation after about 600 roentgens and exfoliation with subsequent ulceration after about 1000. There is a threshold dose below which no somatic effect is clinically observable. The same radiation dose given in fractions at intervals is less effective than when given all at once.
Late somatic effects may extend to two years and there is no threshold dose below which their probability falls to zero. Examples of these late somatic effects are the increased leukaemia and cancer of atom bomb victims and the increased leukaemia and shortened life span of physicians who worked with X-rays during the first decades of this century with insufficient protection. A number of questions, however, need further research and epidemiological studies before a clear understanding of the role and importance of somatic late effects can be obtained.

Genetic effects are stochastic by nature and, at least for point mutations, it is assumed that no threshold or tolerance dose exists and that all radiation effects during the reproductive period accumulate. Quantitative estimates of the mutation rate caused by ionizing radiation are based exclusively on animal experiments, the amounts employed ranging from three to 80 roentgens, which may double the rate naturally occurring. Evaluations of the risk/benefit relation for radiation exposures of individuals and populations have been undertaken during the last decade by UNSCEAR, ICRP and other bodies.

3.2 Risk evaluation for personnel

For the radiation exposure of staff engaged in radiation medicine the same criteria have to be applied as for any other radiation worker. The maximum permissible dose (MPD) for workers is recommended by the ICRP and is internationally accepted; the principle is that any risk of somatic effects should be excluded and that late somatic risks for the individual should be comparable to the other health risks of professional life that have to be accepted as within the bounds of normal. In fact, the monitoring of the radiation exposure of medical radiological staff in different countries shows that 75-96 per cent. are exposed to only one-tenth or less of the MPD.

The risk of somatic late effects can be kept very low and is mostly negligible for the persons involved. Somatic effects, e.g. radiation burns of the fingers or face, which were not uncommon in the early days of radiation medicine, do not occur when the radiation protection meets the prescribed level; the few reports within the last two decades describing such effects indicate non-fulfilment of the requirements. It is evident that such casualties can and must be avoided.

3.3 Risk evaluation for patients in diagnostic radiology

Regarding the risks for patients in diagnostic radiology, it should be emphasized that somatic effects are in no case justified by any medical indication for the diagnostic procedure. The few cases reported during that last three decades of skin damage to patients were the result of careless use and unsafe equipment. Late somatic effects, however, have been reported. In this respect, it is necessary to take into account the sensitivity of the fetus to radiation, which is greater than that of adults; radiation exposure of the fetus in utero should be avoided whenever possible.

Special care must be taken with regard to the genetically significant dose (GSD) in patients undergoing radiological examination, as diagnostic radiology is now known to be the main contributor to man-made genetic radiation exposure in industrialized countries. The average annual frequency of radiological examinations, including mass surveys, has been reported in earlier investigations for industrialized countries to vary between 375 per 1000 population (United Kingdom) and 2587 (Japan). Other countries have reported figures of 40 per 1000 population or less. For developed countries, the GSD in milliroentgens per capita per year ranged from 6.8 (Netherlands) to 75.3 (New Orleans, United States of America). Figures available for other countries are 7.1 (Cairo, Egypt) and 5.2 (Thailand). Bavaria
(Federal Republic of Germany) with a relatively high frequency figure of 868 examinations per 1000 population (indicated as frequency of single exposures) reports a GSD of only 13.7 mrd; New Orleans (United States of America) with a lower frequency of 730 per 1000 population has a GSD of 75.3 mrd. It is obvious that the gonadal dose applied in a single exposure of the different body regions is responsible for these differences.

It can be stated that the GSD delivered to patients undergoing diagnostic radiological procedures in highly industrialized countries with well developed facilities contributes about 7-70 mrad per capita per year, or 6-60 per cent. of that of natural background radiation. In developing countries the contribution is a fifth to a tenth of this, or even less, when the same techniques are applied. This contribution to the GSD is acceptable, and there is no reason to discourage diagnostic radiology in developing countries provided that the techniques are up to date and applied by adequately trained personnel.

Radiotherapy presents greater risks of side effects than does radiodiagnosis. The somatic side effects have to be in an acceptable relation to the therapeutic purpose. In the case of somatic-stochastic effects, a number of workers have reported an increased rate of leukaemia following radiation treatment. It is quite clear, however, that any possible somatic late effects are more than counterbalanced by the therapeutic advantages. The GSD to patients undergoing radiotherapy is in any case negligible as compared with that contributed by diagnostic radiology. GSD figures range from 0.6 mrad per capita per year (Hungary) to 28 (Australia), or about 1-16 per cent. of the total GSD delivered medically.

The health risks connected with nuclear medicine are even less than those of diagnostic radiology and radiotherapy. The radiation exposure and the risk to health depend on the radioactivity applied rather than on the radiological method. Somatic injuries are excluded as long as no radioactivity higher than that intended is applied by error.

The somatic late effects are largely negligible, as the radiation doses to the body or specific organs are smaller in most cases than those administered in diagnostic radiology. The GSD from nuclear medicine is, for the time being, negligible, even in developed countries. The frequencies per 1000 population on average are about 1 per cent. or less than those of diagnostic radiology, and range from 1.7 per 1000 population (Japan, 1968) to 10.1 (West Berlin, 1968).

4. FACTORS INFLUENCING RADIATION QUALITY AND RADIATION EXPOSURE

Great differences exist in the GSD and the somatic doses reported for staff as well as for patients, even between countries with equally well developed medical care systems. They can only be explained by differences in frequency of application and/or in technical performance. Technical performance affects not only the doses administered but also the quality of the results obtained and has to be considered from both points of view.

4.1 Frequency of radiation exposure

The radiation dose is linearly correlated with the frequency of exposure provided that the percentage distribution of the types of examination and, in the case of the GSD, the age and sex distribution of the patients are unchanged. A few types of exposure to relatively high doses may have disproportionate effects. Thus, for example, radiological pelvimetry and obstetric examinations in New Zealand contribute 21.3 per cent. to the GSD being only 0.75 per cent. of the total number of exposures. On the other hand, chest examinations in Bavaria, with a frequency of 59 per cent. of the total, contribute only 0.7 per cent. to the GSD. It is clear that radiation is a genetic risk only when applied to the pelvic region and lower abdomen.
4.2 Technical factors in diagnostic radiology

The most important radiation risk is in relation to the GSD. The main conclusions in relation to the GSD are substantially valid, however, for somatic doses to patients and for the exposure of staff, and fortunately also for the quality of the diagnostic information. Radiation quality influences the surface dose as much as sixfold and the gonadal dose up to but not exceeding threefold. The differences in sensitivity of films, intensifying screens, etc., and therefore in radiation dose vary up to eight times. The greatest difference depends on whether the gonads are located within or outside the radiation beam. A difference of 1-2 cm in the position of the field edge, leaving the gonads inside or outside the primary beam, may mean a difference in the male gonad dose of up to 20-30 fold. Collimation of the beam is therefore a most important factor. Collimation also considerably influences the quality of the radiograph and the fluoroscopic image by reducing the amount of stray radiation. In addition, positioning the patient in such a way as to alter the distance between the primary beam and the gonads may also influence the gonadal dose by as much as 20 times. Protection shields for the gonads can reduce the gonadal dose up to 30-600 times, depending on the body region examined and the design of the shield.

For conventional fluoroscopy the dark adaptation of the examiner's eyes is important. If the adaptation is not sufficient the examiner often compensates by increasing the kV and mA and the doses to the patient may be increased 20-70 times.

4.3 Technical factors in radiotherapy

The technical parameters in radiotherapy have to be considered primarily from the point of view of the therapeutic effects rather than the radiation risks. Generally it can be stated that, for the treatment of deeply sited tumours, telecurie therapy, particularly with cobalt-60 units, is the method of choice; it is rapidly replacing conventional deep X-ray therapy. Superficial X-ray therapy plays a part in areas where cancers of the skin are frequent. The intracavitary application of radium and other radionuclides is an important method, particularly for the treatment of cancer of the cervix uteri, which is very common especially in some developing countries. Afterloading techniques in which the applicators are carefully positioned in the patient and the radioactive source is then inserted simply and quickly is considered to be a method of reducing the exposure of the staff that may also improve the therapeutic results.

One factor in radiotherapy that needs particular mention is dosimetry. The IAEA/WHO postal dose intercomparison programme and surveys of dosimetric equipment in some countries have demonstrated errors in physical dosimetry of up to 100 per cent. and for about 20 per cent. of the institutes more than ±10 per cent. These observations refer to cobalt-60 therapy only; for X-ray therapy, particularly superficial X-rays, and including also institutes which are not "top level", the errors to be expected are even higher.

4.4 Technical factors in nuclear medicine

The methods used and the technical factors involved in nuclear medicine are so numerous that only general conclusions and a few examples can be given.

One important factor is the sensitivity of the radiation measuring systems. Reduction of the radiation background can increase the relative sensitivity. By putting measuring equipment in a low background room or employing other shielding measures the amount of radioactivity required to provide diagnostic information can be reduced at the same time as the risk to the health of patients and staff. Another method of reducing radiation exposure without any loss of medical information being involved is to use radionuclides
with short physical half-lives. A good example of this is the use of radioisotopes extracted from a generator.

4.5 Training and experience in radiation medicine

It is obvious that the quality of radiodiagnosis, nuclear medicine and radiotherapy and the extent of the radiation exposure of patients and staff depend greatly on the knowledge and accuracy of work of the staff involved. Training is therefore of vital importance.

4.6 Organization in radiation medicine

Because of the cost of radiation medical services, they should be centralized as far as the socio-economic structure permits. Centralization facilitates the use of trained manpower, ensures better supervision and so accuracy and makes a greater variety of equipment and methods available. On the other hand, in extended areas with a scattered population, it may be advantageous to decentralize; the diagnostic radiological services particularly should be made readily accessible.

5. PRESENT STAGE OF DEVELOPMENT OF RADIATION MEDICINE

5.1 Staff available to practise radiation medicine

The performance of any medical service is affected more by the number and the quality of staff providing the service than by the equipment and facilities available, provided that there is the necessary minimum of these. This is true also of radiation medicine, although it can be practised to some extent, occasionally or regularly, by physicians and technical staff not trained as specialists. The position as regards staff available for the practice of radiation medicine may be seen from the following figures, taken from the World Health Statistics Annual. The total number of physicians per million population is 2205 for the USSR, 1477 for the United States of America, an average of 1365 for Europe (excluding the USSR), and only 496 for Latin America and 73 for Africa. The corresponding figures for diagnostic and therapeutic radiologists are: USSR, 95; United States of America, 55; Europe, 35 (excluding the USSR); Latin America, 7; Africa, 1. The percentage of radiologists ranges from 4.3 per cent. to 1.4 per cent. of the total number of physicians. The technical staff available per million population is 377 (United States of America), and 6 (Africa), or respectively 26 per cent. and 8 per cent. of the total number of physicians. There are, therefore, some 30 times more physicians in the highly developed than in the developing countries, but 60 times more radiologists and 100 times more technical staff. Moreover, in the developed countries the number of staff engaged in radiation medicine is still increasing, as is the use of radiation for medical purposes, which shows that even in these countries the demand is not yet satisfied.

5.2 Radiological equipment and facilities

It is difficult to evaluate the situation as regards equipment and facilities for radiation medicine, since complete information is not available, particularly in respect of diagnostic radiology, conventional radiotherapy and nuclear medicine. There are, however, reports showing that in the United States of America there are 525 diagnostic and 15.4 therapeutic units per million population, whereas for Thailand (where the medical services are among the most developed in the South-East Asia Region) the corresponding figures are 20.5 and 1.2, and for an African country 9.8 and 0.1. These figures indicate that in highly developed countries radiological diagnostic facilities are between 20 and 50 times greater, and radiotherapy facilities between 15 and 150 times greater, than in developing countries. Moreover, many of the installations in developing countries are out of date and the diagnostic equipment particularly is not infrequently unsafe. In the case of high-energy radiotherapy equipment, Switzerland, for example, has five installations per million population whereas India has less than 0.1, and some of the smaller developing countries have none at all.
5.3 Frequency of applications

The figures available for the frequency of radiation medicine applications are also difficult to evaluate. Most of them relate to parts of countries and there may be wide variations between different parts of the same country, the rural areas in particular being generally less advanced as regards radiation medicine, even in the developed countries. In addition, the term "application" (or "examination") is used differently in the statistics; sometimes all the diagnostic exposures relating to a single case are counted as one application, and sometimes each exposure is counted.

From the 1972 report of UNSCEAR, it can be seen that the annual frequency of diagnostic X-ray examinations per 1000 population varies from 39 (Thailand) to 2587 (Japan); the average for 21 countries (most of them developed countries) is 639, including 27 surveys. The figures for developing countries, which refer mainly to selected areas (such as district capitals) where radiation medicine is better developed, are mostly between 25 and 135, at the extreme below 10. The frequency of X-ray diagnostic examinations is therefore on an average between 10 and 100 times greater in developed than in developing countries.

Similar or even greater differences are found for radiotherapy and nuclear medicine.

5.4 Forecasts for the future

In the developed countries in general the annual increase in the different branches of radiation medicine ranges between 2 per cent, and 15 per cent. The United States of America forecasts an annual increase of 2 per cent. in radiological examinations, 2 per cent. in radiotherapy, and 15 per cent. in nuclear medicine. In the developing countries the rate of increase will depend on their socio-economic development and on the availability of trained manpower, rather than on needs.

In many countries there is practically no radiation medicine, not even the diagnostic radiology that should form part of the basic health services. In the case of radiological diagnosis, the problem is one of training physicians and, particularly, technical staff. Radiotherapy is even less developed, probably because in many countries with limited resources higher priority is given to other health problems than to cancer. As the age of the population increases and cancer becomes a more important problem, it may be expected to develop further.

In the large medical centres of a number of countries nuclear medicine is better developed than radiotherapy, but further development is needed. Nuclear medicine may also be of great value to the developing countries, particularly for solving specific problems of preventive medicine, for example in connexion with nutritional diseases.

6. THE OPTIMUM USE OF RADIATION MEDICINE

In studying the question of the optimum use of ionizing radiation in medicine, consideration needs to be given to:

(a) the socio-economic and health background of the country or region concerned, including the prevalent diseases and their influence on the health of the population;

(b) the overall development of the medical care and preventive medicine systems, particularly their distribution, the preventive or therapeutic measures possible for the main diseases, and the therapeutic facilities available;

(c) the availability of adequately trained manpower, the possibilities of using, part-time, staff trained only in some aspects of radiation medicine, and the training facilities available and that might be established;
(d) the availability of facilities and equipment, in the context of all the resources available for health services and the economic situation of the country;

(e) the priorities to be given to the different branches of radiation medicine in order to obtain the optimum diagnostic and therapeutic results;

(f) the frequency of application needed to obtain the best effects with the lowest possible radiation risk to health and at the lowest cost;

(g) the selection of methods and equipment in relation to effects, risks and costs;

(h) the application of the methods of choice in relation to the quality of the diagnostic and therapeutic results as well as to the radiation risks involved; and

(i) the influence of radiation protection supervision and inspection on performance and on the radiation exposure of patients and staff.

6.1 Radiation medicine in health service context

The development of radiation medicine has to be carefully harmonized with the general development of health services. In countries where, for example, the basic health services are being developed and extensive areas still lack medical care, basic X-ray services may be made available in a few selected areas and limited radiotherapy, nuclear medicine and specialized X-ray services might be established in a central area (usually the capital) to deal with selected patients and provide education and training.

6.2 Priorities within radiation medicine

As regards priorities for the three branches of radiation medicine, any decision depends on the local situation. Where little or no radiation medicine is available, in principle radiodiagnosis should be developed first. Radiotherapy needs to be developed in countries in which cancer is or will be common. In countries where communicable or nutritional diseases predominate and cancer is not yet important, a consideration to be borne in mind is that building up a proper radiotherapy service needs approximately five years, so that any decision to start a radiotherapy service needs to be taken at least five years beforehand.

Nuclear medicine should normally be introduced in places where organized radiodiagnostic and radiotherapy services are already available. In special situations, however - as in countries where nutritional diseases are prevalent - the promotion of specific branches of nuclear medicine might be justified before radiotherapy is well developed.

Medical physics, particularly medical radiation physics, should certainly be developed in any country where radiotherapy plays more than a marginal role. In countries where only radiodiagnosis is undertaken, the services of medical physicists may be limited to occasional visits by experts from surrounding areas or countries or experts from international organizations.

6.3 Training and education of staff

The most important factor in establishing good radiation medicine services and so reducing radiation risks is adequate training of the physicians, medical physicists and technical staff. The most effective way to improve practice is therefore to improve the educational system and ensure that insufficiently trained persons do not practise. Compromises have to be accepted under special conditions; although it is preferable that diagnostic radiological examinations should be performed by specialist radiologists, this is not possible in many countries because of the lack of such specialists or shortage of physicians as a whole. Obviously only specialists can be employed for radiotherapy and nuclear medicine.
Generally speaking, the standard of radiation medicine practised depends on the quality of the technical staff. The standard of radiotherapy and nuclear medicine is particularly dependent on the quality of the medical physicist.

6.4 Methods applied and equipment used

Under certain conditions, particularly in developing countries, simpler equipment and methods are not only cheaper but also more effective than more sophisticated equipment and methods. Some radiation medicine - e.g. cardioangiography - requires very sophisticated equipment. As regards the risks involved in radiation medicine, any method is acceptable as long as it is applied properly and with adequate equipment. Much equipment in use is out of date and dangerous.

Conventional X-rays for deep therapy should be replaced by telecurie therapy, preferably with cobalt-60 units, and other modern methods should be introduced into radiotherapy. Particular attention needs to be drawn to dosimetry, the accuracy of which is a prerequisite for good therapeutic results. Radiotherapy centres should use adequate dosimeters, which need to be checked and recalibrated regularly.

6.5 Frequency of application

The number of applications of radiation medicine should be defined by needs rather than by considerations of risk. In most countries, the number requires to be increased in order to make the optimum use of radiation facilities. Because of cost and risks of exposure, unnecessary and, particularly, repeated applications should be avoided. There should be a strict medical indication for applications involving relatively high doses to the gonads, e.g. examinations of the pelvic region, of young patients, and particularly of the fetus in utero. The same applies to radiotherapy for benign diseases.

The multiplication of the frequency of application by two or more in developed countries and 20 or more in developing countries is acceptable and entails no undue risk, provided that care is taken and radiation protection is ensured.

6.6 Radiation protection services

In many cases proper techniques can be ensured only by constant supervision. Measuring the radiation doses administered to patients and received by staff is the most effective way of convincing the user and improving techniques. Specific attention should therefore be given to the provision of adequate radiation protection services. In this context, up-to-date information is needed on the number and performance quality of radiological installations, the number of applications, etc.

7. WHO PROGRAMME IN RADIATION HEALTH

When considering the Radiation Health programme activities of WHO three phases may be distinguished in accordance with the wishes and the resolutions of the World Health Assembly.

The first programmes of WHO arose out of concern with radioactive fallout caused by atomic weapon tests and by the increasing use of atomic energy. They covered the biological effects of ionizing radiation, evaluations of risks and benefits, the responsibilities of public health authorities, and a number of problems in radiation medicine, including radiation epidemiology.
The programme then focused on providing practical advice to developing countries, particularly on the development of radiation medicine services. In co-operation with UNICEF and the X-ray industry, a field trial of basic radiodiagnostic equipment was carried out, the results of which are available. Guidelines on the organization and management of diagnostic radiology services and the training of staff (radiological technicians, medical physicists) were elaborated. Training courses on the organization and operation of radiation protection services have been established, particularly in relation to the medical uses of ionizing radiation and to the maintenance and repair services needed for radiological equipment. Manuals have been prepared, or are under preparation, mostly in co-operation with the IAEA, on radiation haematology, radiation protection in the different medical applications of radiation, radiation dosimetry, and other subjects.

Consultations on calibration procedures for dosimeters have taken place. A network of regional reference centres for secondary standard radiation dosimetry has been begun and will be completed in the coming years.

A co-ordinated study is taking place, with more than 20 participating laboratories, to evaluate methods of chromosome aberration analysis for the early detection of biological radiation effects on man. Research has been initiated on radiation protection (in co-operation with ICRP); measuring methods, including the proper definition of quantities and units of radiation of different types and radioisotopes (in co-operation with ICRU); strontium-90 levels in human bones from radioactive fallout, particularly in the southern hemisphere (in co-operation with UNSCEAR); and physical problems connected with the diagnostic and therapeutic uses of radiation.

The regional programmes consist mainly of advice by staff and consultants, assistance for film badge monitoring services; postal dose intercomparisons (in co-operation with headquarters and IAEA) to check the accuracy of clinically applied dosimetry in the large radiotherapy centres using cobalt-60 telecurie therapy, assistance to national training schools for technicians and regional training centres for medical physics; the organization of seminars and training courses for radiation protection; and the provision of fellowships for training in the different branches of radiation health.

The proposed future WHO programme aims at better use of radiation medicine in the light of modern trends in the various biomedical fields. It can be summarized as follows:

7.1 Direct assistance to governments

WHO assistance in this respect should include:

1. Training

It should include:

(a) The formulation of training schemes and internationally acceptable curricula for:

(1) specialists in the different branches of radiation medicine;

(2) physicians working part-time in diagnostic radiology only;

(3) medical radiation physicists;

(4) radiological technicians in the different branches of radiation medicine;

(5) engineering technicians for the maintenance and repair of radiological and electromedical equipment;
(6) advisers and inspectors for radiation protection services.

(b) Regional and inter-regional seminars dealing with the above-mentioned schemes and curricular.

(c) Training courses for radiation protection services.

(d) Training courses for engineering technicians.

(e) Special training courses for afterloading techniques, telecurie therapy, the use of generators for short-lived radioisotopes, etc.

(f) Establishment of regional training courses for radiation medicine.

(g) Support for national training schools, particularly for radiological technicians and engineering technicians.

(h) Textbooks and other teaching material.

(i) Seminars dealing with organizational and management problems in radiation medicine.

2. Provision of technical advice

Technical advice will be provided in relation to the following subjects:

(a) In many countries of the world it is unrealistic to plan to establish all the radiation medicine specialties now, and priorities are needed. Recommendations on the establishment of radiation medicine services should be made in the light of actual needs.

(b) Since monitoring of the radiation administered to patients and received by personnel leads to improvement of technique, radiation protection services should be established.

(c) Measurement of the radiation doses received by staff can best be achieved by establishing a personal monitoring service using films, either through already established radiation protection institutions or a new service.

(d) In radiotherapy there is evidence that differences of about 10 per cent in the applied dose may affect the therapeutic result and that in many institutions the errors are much greater. Until properly calibrated dosimeters are available at all institutes, a postal dose intercomparison service is needed. WHO provides this service in collaboration with IAEA, and it should be continued.

7.2 Technological promotion and support

(a) More guidelines, codes of practice and manuals are needed. It is intended to continue this programme by issuing radiation protection manuals and further guidelines on routine procedures in nuclear medicine.

(b) Specifications for equipment suitable for different conditions - especially equipment for the different levels of diagnostic radiology - will be prepared.
7.3 **Designation of reference centres**

Reference centres are needed and will be proposed for the following fields:

(a) Secondary standard radiation dosimetry;
(b) Nuclear medicine;
(c) Radiotherapy (special methods);
(d) Radiobiology (specific problems).

The main aim is to improve the comparability of results and techniques. The reference centres will also collect and disseminate information and act as training centres.

7.4 **Research**

Research is needed and will be carried out on radiation effects in man, and some physical problems which are common to all branches of radiation medicine. It is proposed to include:

(a) Radiation effects in patients who have received radionuclides;
(b) Radiation effects in children exposed *in utero*;
(c) Genetically significant doses caused by medical applications of radiation in developing countries;
(d) Radiobiological problems connected with radiotherapy;
(e) Biological indicators of radiation effects;
(f) Physical and technical problems of application in radiation medicine, including dosimetry of ionizing radiations and radioisotopes.

7.5 **Co-ordination with other organizations**

Close co-operation between WHO and IAEA is based on the relationship agreement approved by the Health Assembly in 1959 (resolution WHA12.40). Both organizations periodically organize intersecretariat meetings at which co-ordination and responsibilities in relation to the medical use of radiation and radioisotopes and radiation protection are discussed.1

Both organizations are fully informed of each other's activities and programmes and increasingly organize joint projects and meetings. They also have an extensive programme of joint publications comprising proceedings of scientific meetings, manuals on radiation protection, medical radiology, etc. It has also been agreed that Agency publications in the Safety Series dealing with radiation protection, codes of practice regarding radiation safety standards, etc., will be revised and published jointly by both organizations.

The creation of WHO regional reference centres for secondary standard radiation dosimetry was begun in 1968, in collaboration with IAEA, and there are now centres in Bucarest, Buenos Aires, Mexico City and Singapore, with others planned for Bangkok, Teheran and possibly Lagos. In 1970 WHO joined IAEA in organizing a postal dose intercomparison with thermoluminescent dosimeters (TLD). In addition, both organizations are planning to organize jointly nuclear medicine reference centres. These joint activities will continue.

---

Co-operation is continuing with ILO, UNICEF, UNSCEAR and other specialized agencies and non-governmental bodies. UNSCEAR deals with the evaluation of new scientific findings on the biological effects of radiation, dose effect relationships and the risks to populations from all sources of radiation. ICRU establishes recommendations on international systems of radiation units and measurements. ICRP establishes international radiation standards (maximum permissible levels and concentrations) for whole populations and special groups of occupationally and medically exposed persons. These standards are used in national legislation and in international guides and manuals. ICRU and ICRP receive support from WHO.