Chapter 36

RADIATION PROTECTION IN NUCLEAR MEDICINE

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Introduction

The goal of this Chapter is to give a general outline of the essential principles and procedures for radiation protection in a nuclear medicine department where radionuclides are used for diagnosis and therapy.

More detailed recommendations regarding radiation protection in nuclear medicine are given in the publications of the International Commission on Radiation Protection (ICRP, publications 25, 57, 60) and in the ILO/IAEA/WHO Manual on Radiation Protection in Hospitals and General Practice (Volume 2: Unsealed Sources, WHO, Geneva, 1975), on which this Chapter is based. This chapter is not intended to replace the above-mentioned international recommendations on radiation protection, as well as existing national regulations on this subject, but intended only to provide guidance for implementing these recommendations in clinical practice.

One of the basic principles of radiation protection in nuclear medicine is that the radiation exposure of the patient, the staff, and the members of the public should be as low as reasonably achievable, (ALARA principle).

In general, the scope of radiation protection in nuclear medicine includes the following:

1. planning, construction and organization of nuclear medicine departments;
2. organization and administration of radiation protection services within the nuclear medicine department;
3. guidance for the transportation and safe handling of unsealed radioactive sources prior to their use;
4. monitoring of working areas;
5. waste management and disposal;
6. preparation for dealing with accidents.

It should be emphasized that all radiation protection measures in an individual nuclear medicine department should be developed and followed in the light of the above-mentioned international recommendations and national radiation protection regulations.

Planning of a Nuclear Medicine Department

According to the recommendations of the ILO/IAEA/WHO "Manual on radiation protection in hospitals and general practice", nuclear medicine diagnostic departments serve almost all the clinical departments of a hospital, and should, therefore, be located in a central area. From the organizational point of view, the grouping of all diagnostic radiological services in an imaging department has proved most successful in large and medium sized hospitals.

An adequate distance between the diagnostic and therapy departments will avoid the problem of shielding the counting rooms, from therapeutic radionuclide sources and also from teletherapy units, such as linear accelerators, cobalt-60 units, and even conventional x-ray therapy units. This will provide a considerable saving in the cost of the shielding of the equipment.

In planning the premises where the unsealed radioactive services are used for diagnostic and therapeutic purposes, two basic principles of radiation protection should be observed. Firstly, that all unnecessary exposures of the staff and members of the public should be avoided, and, secondly, that exposures should not exceed the dose limits established by the competent local regulatory authority or, in their absence, the dose limits recommended by the International Commission on Radiation Protection (ICRP) and other international organizations.

The radiation measuring equipment used for imaging as well as for in-vitro nuclear medicine studies is highly sensitive and may require additional shielding. The background radiation in these premises should not exceed that in the general premises of the hospital.

Additional shielding may be required in the walls and doors of rooms used for patients who have received high doses of radionuclides such as ^{131}I for therapeutic or even diagnostic purposes at times.

For structural shielding design considerations, an "optimization" process as recommended by the ICRP in its publication No. 60 should be used. For these purposes, movable lead shields are commonly used. In rooms, the walls and doors leading to the corridor should be adequately shielded.

At the planning and design stage, special attention should be given to the provision of a reliable power supply, which is imperative for the normal functioning of modern nuclear medicine instruments.

The ventilation system of the department should be adequate for the requirements and functions of each section of the department (radiochemical laboratory, rooms for storage, preparation and dispensing of radioactive materials, counting rooms, wards for patients, etc.) and should not be connected with the central ventilation system of the building.

When radioactive gases are used, care should be taken to prevent inflow of the air exhaled by patients into the working area. A special exhaust system should be used for this purpose.

Organization, staffing and responsibilities

The International Commission on Radiation Protection recommends that the authority in charge is ultimately responsible for all radiation protection matters associated with the handling, administration, storage, etc. of radionuclides within the establishment or working area and its environment.

In a large nuclear medicine department, the person in charge should appoint a competent specialist to act as radiation safety officer, who will work in close collaboration with the hospital's medical physics and radiation protection departments, wherever they are available.

The main task of such an officer is to provide advice on all matters related to radiation protection in the department and to ensure compliance of appropriate rules or recommendations on radiation protection.

In a large nuclear medicine department, a responsible person should also be appointed to take care of the delivery, storage, and transportation as well as dispensing and waste disposal of radioactive materials. The physician is responsible for radiation protection of the patient and must balance the benefits of the diagnostic and therapeutic procedures against the harmful effects of radiation, in view of the dose delivered to the patient as a result of a particular procedure.

An important requirement for efficient radiation protection measures in a nuclear medicine department is training of the staff. Staff should be instructed in the principles of radiation protection, related to the type of work, at the beginning of employment and given periodic refresher courses during their employment. These instructions should include information on biological effects of ionizing radiation, types of radioactive sources used in the department, counting equipment, principles and practical instructions on radiation protection in the department. Special attention should be given to action of the staff during accidents with radioactive sources and in emergency situations, e.g. during a fire, etc. Clearly written instructions, regarding each type of routine operations with radioactive materials, as well as accidental and emergency situations, should be readily available to the staff.

Depending on the nature of the radionuclides and the types of operation with radioactive materials, the authority in charge may need to establish an area to which access is limited and controlled for radiation protection purposes. Such areas should be clearly marked by using warning signs of radiation danger.

Safe handling of unsealed radioactive sources

Most of the radioactive materials, used for diagnostic and therapeutic purposes in a Nuclear Medicine department, are in liquid form as true solutions, colloidal solutions, suspension, or gases dissolved in liquids. In general, the safe handling procedures depend on the physical form of radioactive materials, their radiotoxicity, the type of operation to be carried out and amount of activity to be handled.

A radioactive source, from the storage to the handling room within the department, should be moved in a special lead container. Operations with radioactive sources involving opening of containers and withdrawal and delivery of their contents are described in the ILO/IAEA/WHO Manual of radiation protection in hospitals and general practice (Geneva, 1982). They are based on the following basic rules:

(a) The operations should be carried out in a laboratory specially reserved for work with radioactive materials.

(b) The glassware and instruments used should be reserved for the laboratory in which the sources are handled and should bear distinctive markings.

(c) Every handling operation involving radioactive material should be conducted with care, precision, and neatness.

(d) Generally speaking, every handling operation requires a certain minimum of preparation. The working surface must be prepared and certain items, including all the instruments that will be needed during the work, must be ready and nearby. A bag of impermeable material into which contaminated waste can be dropped should be placed in an immediately accessible position.

(e) Handling operations that are not routine should be planned in advance and rehearsed with non-radioactive materials.

(f) Operators should wear special apparel - e.g., laboratory overalls and gloves.

(g) Pipetting should never be carried out orally because of the danger of radioactive material entering the mouth.

(h) As far as possible, all receptacles containing radioactive liquids should remain sealed when not in use.

(i) Sources should be returned to storage as soon as possible, when no longer required.

(j) After the handling operation, the technician should clean the working area and monitor all surfaces, equipment, and tools, as well as his own clothing and hands, for contamination.

All necessary precautions should be taken to avoid opening or holding radioactive sources by hand. Tongs and other remote handling devices should be used for these operations. The gamma emitting radioisotopes should be handled from behind a protective sheet of lead glass or a wall made of lead bricks. A plentiful supply of lead bricks should always be available in a nuclear medicine department.

An operation with radioactive gases or aerosols should be carried out in a fume hood or a laminar air-flow cabinet with exhaust ventilation. The ventilation system must be regularly controlled regarding air-flow velocity and directions and effectiveness of the filter. More detailed information on this matter can be found in the book by K. Kristensen "Preparation and control of radiopharmaceuticals in hospitals" (IAEA's Technical Report Series No. 194, Vienna 1979).

All operations with radioactive sources should be carried out carefully but in as short a time as possible.

During the handling of radioactive materials, before their administration to patients, all necessary precautions must be taken to prevent contamination of working surfaces as a result of spillage of liquid, formation of aerosols, etc.

Special attention should be paid to preserve sterility of radioactive liquid sources to be administered parenterally to the patient.

The elution of the short-lived radionuclides from generators, e.g. $^{99}Tc^{m}$ and $^{113}I^{m}$ should be carried out in accordance with the instructions attached to the generators and in complete safety and sterile conditions.

To avoid pipetting by mouth, "remote" pipettes with rubber bulbs, or rubber tubes encased in protective sheaths, should be used. Surgeon's gloves, preferably disposable, should also be used by personnel to avoid contamination of the hands. The washing and decontaminations of small items of equipment after use is always a problem. Therefore, the widest possible use of small disposable items of equipment such as unbreakable sterilized tubing, pipettes, and syringes, which are treated after use as radioactive wastes, should be encouraged. However, such disposable items may not be available in many developing countries and even if available, they may not be economically acceptable.

The working surfaces in rooms, where the handling of radioactive materials is carried out, are usually of stainless steel or covered by plastic specially designed for this purpose. The working surfaces have slightly raised edges to retain any spilled liquid. It is essential that, before the handling of radioactive sources, the working surface is covered by one or more layers of absorbent paper, which can be disposed off easily after use. Cotton wool and paper towels must be available near to the operator. The floor in the dispensing room also should be covered by special leak-proof plastic and walls are painted by a special paint which allows easy cleaning.

It is a general rule that the operations with radioactive sources should never be carried out in every day clothing. It is necessary to have enough special protective clothing (overshoes, caps, jackets, trousers, etc.) in the nuclear medicine laboratory.

Good house cleaning practice (wet-mopping), avoiding raising any dust in controlled and supervised areas of the nuclear medicine department, is obligatory. The access of hospital staff and public to the department should be restricted and personnel dosimeters should be available for medical and technical personnel working in the department. The access of personnel to storage and dispensing rooms, as well as to any other parts of the controlled area, should be strictly limited to staff working in these premises.

As required by some national regulations, and as is always considered to be a good safety practice the following rules should be observed in laboratories and nuclear medicine departments [U.K., NRPB, 1983]:

(a) No food or drink should be brought into the area, e.g. for storage in a refrigerator. Smoking or even carrying of open packets of cigarettes should also be similarly banned.

(b) There should be a ban on the use of handkerchiefs; an adequate supply of paper tissues should be provided to replace them.

(c) Any cut or break in the skin should be covered before a person enters the controlled area. Dressing should incorporate a waterproof, adhesive strapping.

(d) The walls, floor and ceiling and all apparatus in the area should be cleaned often to ensure that contamination is kept as low as reasonably achievable.

(e) It is essential that radioactive solutions to be administered are clearly labelled, indicating the radionuclide, chemical form, and activity at a given date and time. The terms "millicurie" and "microcurie" (where still used) should be written out in full to avoid mistakes.

Special equipment for the safe handling of radioactive materials in hospitals, according to the recommendations of ILO/IAEA/WHO Manual on Radiation Protection in Hospitals and General Practice is needed for the following operations:

(a) Storage: lead bricks, lead shielded containers, remote handling tools.

(b) Transportation within the hospital premises: lead shielded cart, lead shielded containers.

(c) Safe handling: remote pipettes, disposable gloves, remote handling tools, lead shielding.

(d) Preparation and calibration of deliveries: safe handling tools (see above), activity calibration meter (Dose calibrator).

(e) Administration and measurement of radioactive substances: disposable gloves, shielded syringe.

Radionuclides for diagnostic and therapeutic applications are generally stored together. It is desirable that storage and dispensing rooms are separate, but in a small nuclear medicine laboratory, this may not be possible.

Each shipment of a radionuclide should be kept separately in individual lead containers, clearly labelled, and having the required wall thickness. It is recommended that the exposure rate should never exceed 0.2 m Gy/h at a distance of 5 cm from the surface of the containers. If necessary, additional interlocking lead bricks should be used to provide adequate shielding. It is not advisable to keep diluted radionuclide solutions in the storage room, e.g. a small volume of ^{131}I in solution prepared for an individual test dose. Special precautions should always be taken to prevent spillage. The storage room should have an efficient ventilation system.

Remote handling equipment such as tongs, forceps, tweezers and more sophisticated devices, with a ball and socket joint, should be available in storage and dispensing rooms. Other safe handling devices and equipment for transportation have been already mentioned in relation to handling of radioactive sources.

The equipment for preparation and calibration of radiopharmaceuticals and other radioactive sources in dispensing laboratories should include activity meters with the range from 37 MBq to 37 CBq. It should be noted that gamma activity can be measured accurately by the well-type ionization chamber, only if a small volume of the solution (about 0.1/5.0 cm^3) is in the centre of the chamber and a spherical geometry can be assured.

Radioactive sources containing carbon-14 and tritium can be measured by comparison with standard sources in a liquid scintillation counter.

Written instructions for the handling and dispensing of radiopharmaceuticals for diagnostic and therapeutic applications should always be available and periodically reviewed. Good records should be kept in relations to all operations with radioactive materials from delivery to dispensing or disposal. Concerning records, the following information is considered noteworthy:

Regarding the radiopharmaceutical;

Name of radiopharmaceutical,
Manufacturer, and batch number,
Delivery date,
Expiry date,
Activity, and date of measurement,
Volume.

Regarding administration to the patient;

Date and time of patient examination,
Type of study and route of administration,
Volume and activity administered,
Volume and activity remaining in the container.

Protection of patients

With respect to the protection of patients, in relation to diagnostic and therapeutic application of radionuclides, it should be emphasized that a nuclear medicine test or treatment with radionuclides should be carried out by a nuclear medicine physician, only if there is a sufficient clinical justification for these procedures. As a general rule, the radiation dose resulting from the administration of radionuclides should be kept at the lowest possible level but without sacrificing the quality of the necessary information or the desired therapeutic effect.

The measuring equipment including single- and multi-probe counting systems, rectilinear scanners and gamma cameras should be regularly checked, in accordance with recommended quality control procedures [Quality Assurance in Nuclear Medicine, WHO, Geneva, (1982) and Quality control of nuclear medicine equipment, IAEA-TECDOC-317] to ensure that each instrument produces optimum performance with respect to its capability and thus contributes to the reduction of patient dose. The practice of using instruments with poor sensitivity which leads to an increase of the activity of the radionuclides administered to patients, should be avoided.

The radiation dose to some organs (e.g. thyroid) can be reduced by using suitable drugs or other compounds which either block the uptake of radionuclides in organs where its presence is not required for diagnosis or treatment or will accelerate the clearance of radionuclides from the body after the examination has been performed. In this connection,

special care must be taken to reduce the organ doses to children undergoing a nuclear medicine examination.

Special attention should be given by the nuclear medicine physician, if a woman undergoing an examination is pregnant. Due to high radiosensitivity of the embryo and fetus, it is advisable that the examination should be postponed until the end of pregnancy or until the second half of it unless such examinations are unavoidable for clinical reasons and the dose to the fetus is minimal. The possibility of pregnancy should always be taken into account in women of reproductive age and, therefore, the radionuclide examination should be carried out during the ten days from start of menstruation. However, the validity of the ten day rule is a matter of debate at present. The breast feeding should be avoided till the level of radioactivity is low enough to avoid any potential harmful effects to the newborn.

In conclusion, it should be emphasized once again that before an examination or treatment with radionuclides, careful consideration should be given to the effectiveness and risk of such diagnostic or therapeutic procedures, in comparison with effectiveness and risk of other methods which do not expose a patient to radiation. For further information and examples, the report of the WHO Scientific Group on Clinical Diagnostic Imaging, published as "Effective choices for diagnostic imaging in clinical practice", TRS-795, WHO, Geneva 1990, should be consulted.

Handling and disposal of radioactive waste

For practical reasons, all radioactive wastes can be classified as liquid, solid or gaseous wastes. All actions related to disposal of radioactive wastes to the environment must be carried out in full compliance with national regulations on radiation protection.

Liquid wastes include the remains of unused radioactive suspensions and solutions, rinsing water that had been used for cleaning contaminated equipment, water from contaminated laundry, and excreta from patients.

The excreta from patients who have received relatively low amount of activities for diagnostic purposes can be released to the sewage system. When the patient has received the therapeutic amounts of radionuclides, e.g. ^{131}I for treatment of thyroid cancer, the excreta should be released into a specialized sewage system, which could be available in large radio-oncological hospitals or kept in nuclear medicine department in bags or specially constructed containers, until the level of activities allows safe disposal into ordinary sewage system.

The disposal of liquid radioactive wastes into the normal sewerage system should strictly follow the recommendations of national regulations. It should be mentioned that general principles and detailed recommendations on waste disposal are given in an internationally accepted code of practice [Safe handling of radionuclides, IAEA Safety Series No. 1, Vienna (1973)] which is, at present, under revision.

The solid radioactive wastes include contaminated equipment (e.g. vials, syringes, drinking glasses, etc.), laundry, dressings, disposable paper, cotton, etc.

All used linen should be checked for contamination and sent to a specialized laundry or washed in a room specially designed and designated for this purpose. Other solid radioactive waste should be kept in a properly ventilated room until it can be disposed as low-level radioactive waste or the radioactivity decays sufficiently, so that it can be disposed as non-radioactive waste.

The radioactive wastes containing long-lived carbon-14 and tritium should be kept in special containers and sent to industrial waste depositories. However, these two radionuclides are seldom used in clinical nuclear medicine practice.

The handling of cadavers (preparation for burial or cremation) containing substantial radioactivity must be carried out under supervision of the radiation safety officer. Autopsy in such cases is not advisable and must be restricted to minimum handling, if postmortem examination is necessary. All necessary radiation protection measures for the staff and the decontamination of instruments and the working place should be taken, in consultation with the radiation safety officer.

Monitoring and surveillance procedures

The radiation safety rules and procedures in nuclear medicine departments should be established in collaboration with the institution's radiation protection officer, or the local radiation protection authority, if appropriate, and must follow the requirements of the existing national regulations. It is recommended that written instructions be available for all techniques and procedures involving use and handling of radioactive sources and radioactive wastes.

An important radiation safety procedure in nuclear medicine departments is monitoring. According to the statement of the International Commission on Radiation Protection (publication No. 25) radiation monitoring implies the performance of relevant measurements on individuals in the work area and of the environment, and the interpretation of these data for the purposes of controlling personnel exposure and environmental contamination. Monitoring is very important also for the protection of sensitive and expensive measuring equipment, which can become inoperational due to radioactive contamination.

In monitoring, attention must always be given to both external irradiation and radioactive contamination. The choice of equipment for monitoring depends on the media and objects to be monitored and the type of the radiation which is to be measured.

There are many types of instruments which are suitable for the monitoring of gamma and beta irradiation. According to the recommendation of the ILO/IAEA/WHO Manual on Radiation Protection in Hospitals and General Practice, the most practical device is the acoustic dose-rate meter, which gives an audible warning when the wearer is subjected to a high rate of irradiation. As the dose rate increases, the pitch of the sound rises. In addition to this portable warning dose-rate meter, it is advisable to have in the nuclear medicine laboratory a hand and foot monitor, which should be placed at the door of the active room,

containing the radioactive materials. According to the ILO/IAEA/WHO recommendations, in the small departments, an end-window counting tube with long cable permits the monitoring of hands and feet and may also be used for monitoring contamination.

The routine monitoring should be carried out on all persons or things which may have had contact with unsealed radioactive sources, and in areas, where the work with these sources has been performed. This would include protective clothing of the staff, bed linen and patient's clothing, protective gloves, working surfaces, and radioactive wastes. The room should also be monitored after work with radioactive gases and substances which may form radioactive aerosols.

Special attention should be given to the monitoring of staff working with radioactive materials. Additionally, it is recommended that staff be provided with appropriate personnel monitoring devices, such as personal pocket monitors or film badge (or TLD badges).

The IAEA publication [Recommendations for the Safe Use and Regulation of Radiation Sources in Industry, Medicine, Research and Teaching, Safety Series No. 102, IAEA, Vienna, 1990] recommends schemes for monitoring of the work-place and personal dosimetry:

Monitoring for internal contamination is a more difficult task. Usually an indirect assessment of this contamination is made based on an estimate of the quantities of radionuclides entering the body in the working area through inhalation and ingestion; and, in case of accidents, through wounds. The monitoring of internal contamination can be also carried out by radioactive measurement or radiochemical analysis of the biological excreta. This approach is based on the assumption that the biological elimination of a radionuclide from the body depends on its nature and may be expressed by mathematical formulae.

In large nuclear medicine departments with radiochemical laboratories, where ^{35}S, ^{14}C and ^{3}H are used as labelled compounds, appropriate monitoring instruments should be available to check possible contamination in the working areas. Since these radionuclides are pure beta emitters, in case of internal contamination, external measurement is not possible. Therefore, periodic monitoring of the laboratory staff should be carried out by analysis of the excreta (urine) in a well-type scintillation counter.

Appropriate records should be maintained regarding the procurement and the day-to-day utilization of radionuclides, monitoring of working areas, accidents and remedial actions taken, radioactive waste disposal, monitoring of personnel and information on calibration of monitoring instruments.

Measures for dealing with radiation emergencies and accidents.

The most common types of accidents which may occur in a nuclear medicine department involve fire, explosions, spillage of a significant amount of radioactive solution, misplacing or losing radioactive sources, and the inadvertent administration of large activities of radionuclides.

Despite the fact that these events are usually unpredictable, it is advisable that adequate plans and written instructions are prepared in advance to deal with accidents, which may occur in the laboratory. The staff must be trained to implement the plan and strictly follow the instructions in the event of an accident.

When an accident occurs, the hospital administrative authorities, the nuclear medicine department head and the radiation protection officer must be informed immediately and necessary remedial measures must be taken.

In case of a serious accident, involving bodily injury, the first priority is to give first aid to the persons, affected by the accident. Then, assisted by suitable monitoring instruments, radioactive substances should be removed from the skin, hair and other parts of the body by using physical methods. Contaminated, small wounds can be washed, preferably with a product that makes the radionuclide insoluble, e.g. magnesium sulphate for the alkaline earth elements or chelating agents which form complexes with high valence elements.

In case of contamination through the gastro-intestinal or respiratory tract, the decontamination measures should be carried out under the supervision of a trained physician.

Within the area affected by the accident, action must be taken to prevent further spread of contamination or the intake of radioactive materials.

The borders of the contaminated area must be clearly marked and the decontamination of the working surfaces should be carried out by using physical methods (absorbent materials, washing with detergent and water) and then using recommended chemical compounds. A recommended list of chemicals for use in such circumstances should be available in the nuclear medicine department.

Protection of personnel and members of the public.

The radiation protection principles and rules for clinical staff of the nuclear medicine department and, in particular, for personnel involved in the preparation and administration of radionuclides are based on the concept of optimization in radiation protection and dose limits established by the national regulations, in accordance with international recommendations. These limits should not be exceeded during the work with unsealed radioactive sources in the department. Every effort should be made to keep these limits as low as reasonably achievable.

The International Commission on Radiological Protection [ICRP Publication 60, 1990] recommends a limit on effective dose of 20 mSv per year, averaged over five years (100 mSv in five years), with a further provision that the effective dose should not exceed 50 mSv in any single year. The five-year period would have to be defined by the regulatory agency, e.g. as discrete five-year calendar periods. It is implicit in these recommended dose limits that the dose constraint for optimization should not exceed 20 mSv in a year. It is assumed

that the dose constraints may be established on basis of "conclusion about the level of individual doses likely to be incurred in well-managed operations".

Usually the amount of radioactivity administered to the patients for diagnostic purposes is small and does not create any hazards for medical and auxiliary personnel, because of external irradiation from the patient. In this case, radiation protection efforts are concentrated in ensuring that the necessary precautions are observed during the process of preparation and administration of radiopharmaceuticals.

The main danger for personnel from external irradiation arises from the patients and their excreta, when therapeutic amounts of radionuclides are administered. The contacts of the staff with these patients, particularly during the first few days after the administration of radionuclides should be limited to the most essential visits, examinations, and procedures. The installation and use of television systems for remote surveillance is highly desirable if practicable. Special precautions should be taken during the collection, storage and disposal of excreta. After optimizing the working procedures, the rotation of personnel could be used to ensure that dose limits established for the staff is not exceeded.

The employer shall ensure that each female worker engaged in work with ionizing radiations is informed of the possible resulting danger to the foetus and the importance of informing the employer as soon as she knows that she is pregnant.

When a female worker declares that she is pregnant, the employer shall take all reasonably practicable steps to ensure that working conditions, including the likelihood of accidents, are such that during the remainder of her term of pregnancy the dose to the surface of her abdomen is less that 2 mSv and the dose to the woman from radionuclides intake is less than 1 mSv.

Regarding protection of members of the public, who may have personal contact with patients, who have received diagnostic amounts of radionuclides, it should be pointed out that this does not create any hazard because of external irradiation. It is only necessary that the members of the patient's family are instructed by medical personnel regarding the basic rules on how to collect excreta, if such collection is necessary.

The possible contact of members of the public with patients, to whom therapeutic amounts of radionuclides are administered, is a more serious problem. Measures should be taken to avoid exposures, in excess of the dose limits established for members of the public. Visits to patients, who are hospitalized in special wards after administration of therapeutic amounts of radionuclides, should be limited and a reasonable distance should be kept between visitors and the patient's bed.

The possible visits to a patient by pregnant women and children should be restricted to the most indispensable circumstances.

After treatment is completed, the patient may be allowed to leave the hospital, when the activity in his body does not exceed the level recommended by national regulations.

During the travel to his home, it is advisable that the patient be accompanied by a member of the medical staff to prevent contamination of the environment and other people, if the patient needs to vomit or excrete. (This may not be practical in cases where public transport has to be used.) Members of the family should be instructed regarding precautions against possible contamination and how to minimize their exposure to external irradiation from the patient's body.

SUGGESTED READING.

[1] INTERNATIONAL COMMISSION ON RADIOLOGICAL PROTECTION, Annals of the ICRP. Publication 25 "The Handling, Storage, Use and Disposal of Unsealed Radionuclides in Hospital and Medical Research Establishments. Pergamon Press, Oxford, New York, Frankfurt, 1977.

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[7] NATIONAL RADIOLOGICAL PROTECTION BOARD, 1983. Draft guidance notes for the protection of persons against ionizing radiations arising from medical and dental use. (Quotation from R.F. Mould "Radiation Protection in Hospitals" Bristol and Boston, 1985).

[8] R.F. MOULD, R.F., Radiation Protection in Hospitals. Adam Hilger Ltd., Bristol and Boston, 1985.

[9] Atomic Energy Regulatory Board, Nuclear Medicine Laboratories. Safety Code for Nuclear Medicine Laboratories (DRAFT). Bombay.

[10] Recommendations for the Safe Use and Regulation of Radiation Sources in Industry, Medicine, Research and Teaching. Safety Series No. 102, IAEA, Vienna, 1990.