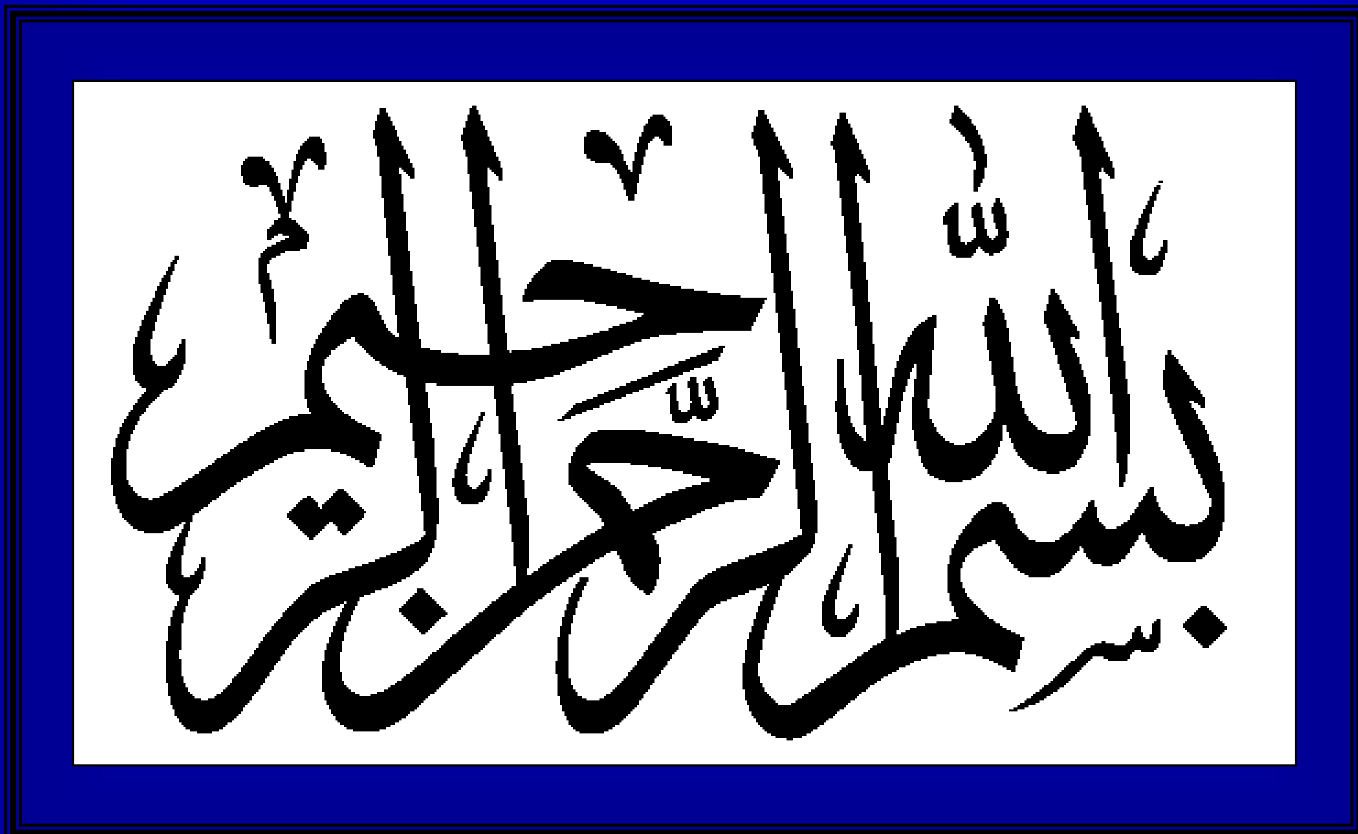
بسم الله الرحمن الرحيم

Radiation Protection

RADIATION SAFETY In RadiOtherapy

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Understanding Radiation

Soon after Roentgen discovered x rays in 1895 and Becquerel discovered natural radioactivity in 1896 it became apparent that ionizing radiation was **not only useful for the diagnosis and treatment of disease but was also harmful to human tissue** through:

- Direct clinical effects at very high doses.
- Potential for delayed effects such as induction of malignancies.
- Potential for genetic effects

Definition

Radiation Protection (also called radiation safety) is applied Radiation Physics and Radiobiology.

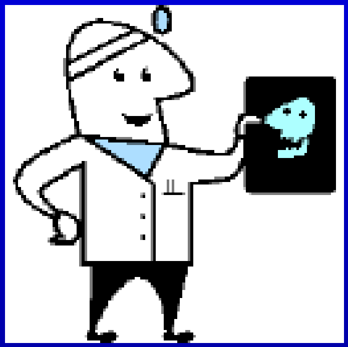
When principles of Radiation Physics and Radiobiology are applied in clinical setting the patient dose is limited to the lowest possible amount.

The Goal

Provide the radiation workers with knowledge and the attribute necessary to provide radiation protection to protect the patient, themselves and others from the potentially harmful effects of radiation.

Radiation Safety; Whom are we protecting?

- Patient



- Physicians & Staff

- General Public

Risk of Radiation

Risks associated with radiation exposure **can only be restricted but cannot be eliminated entirely** because:

- Radioactive substances producing ionizing radiation occur naturally and are permanent features of the environment. (Responsible for a worldwide average dose of 2.4 mSv per year, of which 1.2 mSv is due to radon and its daughter products.)
- Man-made radiation sources are now widespread.
- Sources of ionizing radiation are essential to modern life, in health care, industry, and agriculture.

Theoretical Background to Radiation Protection

Exposure to radiation can cause detrimental health effects that fall into one of two categories:

- **Deterministic**
- **Stochastic**

Theoretical Background to Radiation Protection

Stochastic Effects / Probabilistic

- Have no threshold levels of radiation dose.
- The probability of the effects is proportional to the dose.
- A latent period is seen between the time of exposure and the events to manifest
- Severity independent of dose received
- Seen when the cells are modified rather than killed.

Non stochastic effects/ Deterministic

- Have definite threshold levels of radiation dose.
- The probability of the effects is proportional to the dose.
- A latent period is seen between the time of exposure and the events to manifest
- Severity may be proportional to the dose received.
- Seen when the cells are killed or loose capability to divide.

Theoretical Background to Radiation Protection

- **Risk Estimation**

  The risk associated with the genetic effects of radiation is smaller than the risk of induction of cancer (UNSCEAR 2001), so it is the latter that is the principal consideration in determining dose limits.

  - **Effect of Age at Exposure and Lifetime Risk**

    Cancer induction by radiation has a latent period:

    Early taken to be 10 years for solid cancers and 2 years for leukemia.

Types of Radiation Exposure

IAEA Basic Safety Standards (BSS) defines two types of exposures:

- **Normal exposure** results from certain industrial or medical practices and is of predictable magnitude albeit with some degree of uncertainty.

- **Potential exposure** is an unexpected but feasible exposure that can become **actual exposure,** if the unexpected situation does occur, for example, as a consequence of equipment failure, design problems or operating errors.

Types of Radiation Exposure

BSS specifies means for controlling normal and potential exposures:

- **Normal exposures** are controlled by restricting the dose delivered. *For example*, exposure of patients is controlled through delivering only the doses that are necessary to achieve the diagnostic or therapeutic objective.
- **Potential exposures** are controlled by optimizing the design of installations, equipment and operating procedures.

Types of Radiation Exposure

The radiation exposures covered by the **BBS** encompass normal and potential exposures of **three distinct groups**:

- **Workers** pursuing their occupations (occupational exposures).
- **Patients** in diagnosis or treatment (medical exposures).
- Members of the **public.**

Radiation exposures are thus divided into **three categories:**

- **Occupational exposure.**
- **Medical exposure.**
- **Public exposure**

Radiation Protection Regulation

OCCUPATIONAL EXPOSURE

Control of exposure to radiation is achieved partly by the designation of areas of work where there is a potential for such exposure.

Designated Areas:

- **Controlled area:**

  Controlled areas are specific zones that have special rules to protect people from ionizing radiation and to prevent the spread of radioactive contamination. Access to these areas is restricted and monitored to ensure safety. (In Britania effective dose greater than 6 mSv a year or 15 mSv in the case of the lens of the eye).

Radiation Protection Regulation

OCCUPATIONAL EXPOSURE (IAEA)

In radiotherapy **practice controlled** areas are:

- All irradiation rooms for external beam radiotherapy.
- Remote after-loading brachytherapy treatment rooms.
- Operating rooms during brachytherapy procedures using real sources.
- Brachytherapy patient rooms.
- All radioactive source storage and handling areas.

Radiation Protection Regulation

OCCUPATIONAL EXPOSURE

- **supervised areas:**

The area that occupational exposure conditions need to be kept under review. **(**In Britania, the areas where there is a possibility of exposure exceeding the general public limit of 1 mSv (HSE 2017).

- **Unsupervised area:**

In Great Britain te place that the regulations (ECD 2013; HSE 2017) set a exposure limit of 1 mSv per annum.

Radiation Protection Regulation

OCCUPATIONAL EXPOSURE (IAEA)

Individual monitoring and exposure assessment.

- The The purpose of monitoring and exposure assessment is to gather and provide information on the actual exposure of workers and to confirm good working practices contributing to reassurance and motivation.
- The BSS requires individual monitoring for any worker who is normally employed in a controlled area and who may receive a significant occupational exposure.
- In a radiotherapy department the personal dosimeters should be exchanged at regular intervals not exceeding 3 months.

Radiation Protection Regulation

OCCUPATIONAL EXPOSURE (IAEA)

Monitoring the workplace.

BSS requires licensees in cooperation with employers to develop programmes for monitoring the workplace.

Initial monitoring:

- Is to be conducted immediately after the installation of new radiotherapy equipment and after the replacement of a teletherapy source and remotely controlled brachytherapy sources.
- Should include measurements of radiation leakage from equipment as well as area monitoring of occupied space around irradiation rooms.

Radiation Protection Regulation

OCCUPATIONAL EXPOSURE (IAEA)

Dose limits

Limits are set with a view towards ensuring that no deterministic effects can occur and that risks of stochastic effects are kept acceptably low. (Mayles 1186)

The annual effective dose limit for uniform irradiation of the whole body of 20 mSv (ICRP)

It is permissible to exceed 20 mSv in any one year, but the dose should never exceed 50 mSv in a year.

Radiation Protection Regulation

OCCUPATIONAL EXPOSURE (IAEA)

Pregnant workers

The notification of pregnancy shall not be considered a reason to exclude a female worker from work; however, the employer of a female worker who has notified pregnancy shall adapt the working conditions in respect to occupational exposure so as to ensure that the embryo or fetus is afforded the same broad level of protection as required for members of the public

Radiation Protection Regulation

PUBLIC RADIATION PROTECTION

In Publication 103, the ICRP recommends an annual effective dose limit of **1 mSv** for individual members of the public.
However, it also recommends that, in special circumstances, a higher value of effective dose could be allowed in a single year, provided that the average over 5 years does not exceed 1 mSv/year.

Radiation Protection of Staff and the Public

Component of radiation

Three principal components may require shielding. These are:

- **The primary beam.**

  The primary beam is the first consideration in designing shielding.

- **Leakage radiation.**

  Leakage radiation is emitted by the equipment outside the useful (i.e. primary) beam of radiation.

- **Scattered radiation**.

  Scatter may arise either from the walls of the room (including floor and ceiling) or from the patient. It will be of lower energy than the leakage radiation,

For high-energy accelerators, there may also be significant production of neutrons..

LEAKAGE RADIATION

By law (FDA), for kilovoltage x-ray units the **maximum permissible leakage radiation exposure at 1 meter from a diagnostic x-ray tube is 0.1 R/hour** with the tube operating continuously at its maximum kVp and mA.

For Cobalt 60 machine according to the IEC in the beam-off condition, the absorbed dose rate at one meter from the source must not **exceed 0.02 mGy h^{-1},** and at a distance of 5 cm from the protective surface of the head**, must not exceed 0.2 mGy h^{-1}.** In some countries the 0.02 mGy h^{-1} figure is reduced to 0.01 mGy h^{-1}.

LEAKAGE RADIATION

For linear accelerators, leakage radiation can arise from:

The waveguide, radiofrequency source, beam-transport system, target, filters, collimators, etc.

Shielding materials required may be heavy and occupy considerable space.

The International Electro technical Commission (IEC) specification (IEC 2016) is for leakage tube **less than 0.1% of the useful beam,** but modern accelerators usually have less leakage.

Neutrons and Induced Radioactivity

In high-energy linac (above 10 MV), neutrons are produced by:

- **X ray - neutron (X,n) reactions.**
- **Electron - neutron (e,n) reactions.**

Neutron contamination is produced by high energy photons and electrons incident on the target, primary collimator, beam flattening filter, collimator jaws, beam accessories, air and patient.

Neutrons and Induced Radioactivity

Neutron contamination can be **a direct or indirect hazard** for patients in the treatment room and individuals in areas surrounding the linac bunker.

In the indirect hazard,

neutrons can activate other elements (neutron activation), which remain radioactive and will contribute to the radiation exposure of radiotherapy staff entering the treatment room after a high energy photon beam treatment.

The intensity of this activity will increase with prolonged running of the linear accelerator and is a particular hazard to maintenance staff.

Neutrons and Induced Radioactivity

Neutrons rarely contribute **above 0.5%** of the equivalent dose at the isocenter.

The tenth-value-thickness (TVT) for neutrons absorbed in concrete is lower than that for photons. As a consequence, the shielding provided against photons will be adequate for neutrons.

Neutrons and Induced Radioactivity

Radioactivity in the treatment room air is removed by efficient room ventilation, which also handles the removal of ozone and noxious gases produced by photon interactions with air.

Typically, there are **5 – 8 exchanges of air per hour** in a high energy linac room.

MEDICAL EXPOSURE

Requirements on justification and optimization of protection apply to medical exposure but not to dose limits.

Dose constraints do not apply to the exposure of patients as part of their own diagnosis and treatment.

Justification of medical exposure

Medical exposures should be justified by weighting the diagnostic or therapeutic benefits they produce against the radiation detriment they might cause, taking into account the benefits and risks of available alternative techniques that do not involve medical exposure.

MEDICAL EXPOSURE

Optimization of exposure.

In **therapeutic medical exposure,** optimization is achieved by keeping exposure of normal tissue ALARA consistent with delivering the required dose to the planning target volume (PTV).

The process of optimization of external beam radiotherapy should take into account geometric variations in the location of the target and organs at risk throughout the treatment chain by creating a planning target volume (PTV) and one or several planning organ at risk volumes (PRVs).

MEDICAL EXPOSURE

Calibration of radiotherapy sources and machines

5% discrepancy in radiation therapy dose results in a clinically significant difference in outcome.

- The calibration of sources used for medical exposure be traceable to a national or international standards laboratory.
- Radiotherapy equipment be calibrated in terms of radiation quality or energy and absorbed dose under specified conditions.
- Sealed sources used for brachytherapy be calibrated in terms of activity, reference air kerma rate in air or absorbed dose rate in a specified medium, at a specified distance, for a specified date.
- The calibrations be carried out at the time of commissioning a unit, after any maintenance that may affect the dosimetry and at regular intervals approved by the regulatory authority."

MEDICAL EXPOSURE

Calibration of radiotherapy sources and machines

Calibration of new equipment and new radiation sources should be performed independently by at least two different qualified experts in radiotherapy physics using different dosimetry systems.

MEDICAL EXPOSURE

Doses Associated with the Verification of Radiotherapy Treatment

The Report of AAPM Task Group 180 (2018) recommends that imaging doses are added to the calculated therapy dose if they exceed 5% of the planned treatment dose.


Thanks for your kind attention