CHAPTER IX

SAFETY INSTRUMENTATION

9.1 INTRODUCTION

The number of medical equipment in a modern community hospital is increasing day by day. In order to avoid electrical shock, excessive radiation, toxic exposure, fire, explosion and other hazards, many of the devices should be desired and handled with extreme care. Dangerous accidents can be kept to a minimum if hospital physicians, health care workers, biomedical engineers and other staff are properly trained to exercise caution and if regulations and procedures are strictly adhered to. Radiation safety and hazards associated with the use of radioisotopes are very important problems for biomedical physicists. Electrical Safety and patient shock hazards associated with the use of biomedical electronic equipment have become important problems for bio-medical engineers.

9.2 RADIATION SAFETY INSTRUMENTATION

Today X-rays and radioisotopes are the powerful diagnostic and therapeutic tools. It is known that these agents for good become agents for evil if they are misused or used without adequate knowledge of their properties. The charged particles like α, ß, protons and electrons from radiation produce ionization directly through coulomb interaction with atomic electrons. The uncharged particles like X-rays and γ-rays from radiation produce ionization thorugh knocking of electrons from the medium. The neutrons produce nuclear reactions

at all energies and through that they produce biological damages. One of the side effects of X-radiation or nuclear medicine is the dose absorbed by the patient and those handling the X-ray machinery and nuclear medicines. It is very useful if one knows about the units of ionizing radiation.

One ***Curie*** is the unit of (radio) activity and is defined as the quantity of any radioactive nuclide in which the number of disintegrations per second is 3.7×10^{10}. The rate of decay of 1 gram of radium gives 1 curie activity. In cancer therapy, the intensity of the radioactivity applied is interms of millicurie and microcurie.

One ***Roentgen*** is the unit of exposure of ionizing radiation and is defined as the quantity of gamma or X-rays required to produce 1.61×10^{12} pairs of ions in 1 gram of dry air at standard conditions of temperature (0°C) and pressure (760 mm Hg). Thus 1 Roentgen (R) = $1.61 \times 10^{12} \times 1.602 \times 10^{-19} \times 1000 = 2.58 \times 10^{-4}$ C/kg in S.I. units. That is, it is the amount of radiation exposure which produces 2.58×10^{-4} coulombs of charge by ionization in one kilogram of dry air at standard temperature and pressure.

One ***rad*** (acronym for radiation absorbed dose) is the unit of absorbed dose of ionizing radiation and is defined as the absorption of 100 ergs of radiation energy per gram of absorbing material. Thus in S.I. units,

$$1 \text{ rad} = \frac{100 \times 10^{-7}}{10^{-3}} \text{ J/kg} = 0.01 \text{ J/kg}$$

That is 1 rad is the absorbed dose of 0.01 Joules of radiation energy per kilogram of absorbing material.

One ***rem*** (acronym for roentgen equivalent man) is the unit of dose of any ionizing radiation which produces the same biological effect as a unit of absorbed dose of ordinary X-rays.

9.2.1 Effects of radiation exposure

In the case of human body, the damage caused by nuclear or ionizing radiation depends on the dose and the rate at which it is being absorbed. It also depends on the part of the body which is exposed to the radiation.

Figure 9.1 shows the variation of the absorbed dose by the body tissues (bone and muscle) at different radiation photon energies for a given exposure. When the radiation photon energy is lying between 20 and 40 keV, bone absorbs maximum energy for a given exposure. But the muscle shows constant amount of absorption irrespective of the radiation photon energies.

The damages caused to the cells are pathological and genetical. The effects of ionizing radiation on human beings with respect to different amount of dose are given below.

Radiation dose (rem)	Effects of ionizing radiation on human beings
0.03	Average dose from chest X-rays
5	Annual exposure limit for the persons who are handling nuclear medicines and X-rays
10	Leukemia and cancer
10 - 25	Changes in blood cells
100 - 200	Vomiting within three hours at about 125 R and hair loss within 5 to 10 days
225	Death within 60 days for 5% of those exposed
400	Death within 60 days for 50% of those exposed
500 - 600	Death within 60 days for 90% of those exposed
> 1000 (in a single exposure)	Vomiting and death within 3 hours

The annual safe exposure limit may decrease year to year in the case of medical attendants, who are handling sources of ionizing radiation. For persons who are handling nuclear medicines, the following precautions are to be taken against radiation hazards:

i) Radioactive materials are kept in thick walled lead containers so that radiation cannot penetrate them.

ii) Lead aprons and lead gloves are worn.

iii) All radioactive samples are handled by a special remote control process using robots.

Any amount of the radiation whether it is below or above permissible level, it always produces biological damage.

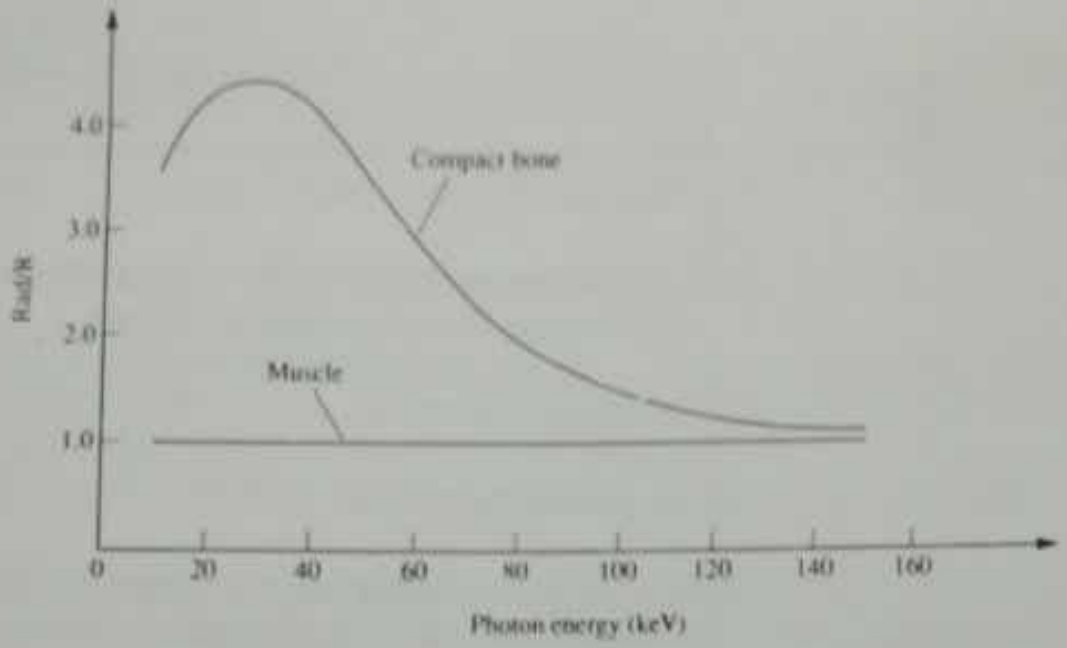

Fig.9.1. Relationship of the absorbed dose to given exposure in bone and muscle over the radiation energy range

The aim of ***radiation protection*** is the prevention of detrimental non-stochastic effect and limitation of the probability of stochastic effects to acceptable levels. The International Commission on Radiological Protection (ICRP) is looked upon as the appropriate body for giving general guidance on the widespread use of ionizing radiation sources. The ***maximum permissible dose*** for an individual is that dose, accumulated over a long period of time or resulting from a single exposure, having a negligible probability of severe somatic or genetic injuries and a minor nature. The maximum permissible dose is given by dose equivalent limits. The dose limits for occupational workers with respect to genetic effects are as follows:

Non stochastic effects

(Production of cataract, shortening of life span and infertility)

Eye lens : 15 rem/year
Other organs : 50 rem/year

Stochastic effects

(Production of carcinogenesis, leukemia and hereditary effects).

Uniform whole body irradiation: 5 rem/year