ISSN- O: 2458 - 868X, ISSN–P: 2458 – 8687
Index Copernicus Value: 68 . 16
PubMed - National Library of Medicine - ID: 101731606

International Journal of Medical Science and Innovative Research (IJMSIR)
IJMSIR : A Medical Publication Hub
Available Online at: www.ijmsir.com
Volume – 5, Issue –3, June - 2020, Page No. : 224 - 232

Radiation Safety In Intervention Radiology

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Citation this Article: Dr. Arindaam Arjunrao Pol, Dr. Rikhit Maganlal, Dr.Monika Nukala, " Radiation Safety In Intervention Radiology", IJMSIR- June - 2020, Vol – 5, Issue -3, P. No. 224 – 232.

Type of Publication: Original Research Article

Conflicts of Interest: Nil

Abstract

The demand for medical imaging has also increased the requirement for radiation safety. These interventional techniques are associated with exposure to high risks to radiation. Few procedures associated with interventional radiology may cause low risk to patients and medical staffs while a number of lengthy and fluoroscopically guided procedures may impose high risk and cause skin injuries. Children are more prone to radiation-related effects than adults. The cell and tissues of children are under rapid growth, which makes them more susceptible to the hazards of the ionizing radiation. Due to long life expectancy, children have the time to express the disease in their lifetime.

In laboratories such as cardiac catheterisation laboratory, ionic radiation is most commonly used. During the procedure, the patients, as well as the health professionals engaged in conducting the procedure, are also exposed to such damage causing radiation, Among all other specialists the cardiologists are at the highest risk of radiation hazard. The adverse effects of radiation exposure can be classified into stochastic effect and deterministic effect Radiation protection is essential and measures must be taken in every circumstance to protect the patient and health professional to safeguard against the detrimental effects of radiation.

The use of protective clothing, shields, monitoring instruments and barriers help in minimising the radiation effects. A 0.5mm lead is known to absorb almost 98% of lead. Leaded gloves may prevent the hands from scatter radiation although may increase the risk of radiation injury from direct rays. Protective eyeshield such as leaded glasses or a 180^0 helmet may be used to prevent radiation harm to the eye lens. Recently, Radpads shields are used to prevent damage caused by scatter rays. For safe operating practices, the training of the healthcare staffs in relation to radiation protection is essential. Adequate training will help to increasing the awareness about radiation protection and reducing the dose of radiation.

Keywords: Radiation protection and prevention of scatter radiation in intervention radiology

Introduction

The demand for interventional radiology has increased drastically with the increase in various disease conditions requiring diagnostic interventions. With the increase in medical imaging, the requirement for radiation safety has also highly increased. These interventional techniques are associated with exposure to high risks to radiation. The main challenge associated with these techniques is protection against harmful rays (1). Although few procedures associated with interventional radiology may cause low risk to patients and medical staffs, a number of lengthy and fluoroscopically guided procedures may impose high risk and cause skin injuries. X-ray examination causes millions of rays consisting of photons to pass through the body of the individuals exposed to the radiation. These photons can damage any molecule in the body (2).

Damage caused to the DNA or a part of a chromosome may cause altered effects such as leading to the formation of a tumour. Exposure of such rays to certain regions of the body may cause less harm while exposure to the brain, salivary gland, and thyroid gland may be increased (2). Children are more prone to radiation-related effects than adults. The cell and tissues of children are under rapid growth, which makes them more susceptible to the hazards of the ionizing radiation. The high doses of CT scan maintained for adult requirement could cause a mutagenic effect on children. Due to long life expectancy, children have the time to express the disease in their lifetime (3).

Involvement of health care professionals

The X-rays mainly travel in straight lines. The rays mostly do not reflect; rather scatter after coming in contact with an object or a person, primarily the patient. It causes exposure to the X-ray technicians and radiologists. The healthcare workers are engaged in taking X-ray for longer periods of time everyday and thus, result in exposure to hazards. In the modern laboratories such as cardiac catheterisation laboratory, ionic radiation is most commonly used. During the procedure, the patients, as well as the health professionals engaged in conducting the procedure, are also exposed to such damage causing radiation (4). Various studies have reported that among all the interventional specialists, the cardiologists are at the highest risk of radiation hazard (5).

Hazards of prolonged exposure to radiation

The radiation absorbed in the body may cause various effects. The physical and chemical reactions caused by the rays may cause biological effects in the human body. The effects may be genetic or caused in the cells and chromosomes due to the penetrating rays. The cells may be affected by the deterministic effect. The deterministic effect is caused when the number of cells lost due to the effect of radiation cannot be replaced by new cells. Although a small loss of cells does not affect the body functions, damage to body organs or a large part of the cells cause a painful experience. Damage to a part of a chromosome may lead to life-threatening diseases such as cancer. Radiation exposure may cause:

Brain tumours: There are various studies which reveal the presence of a brain tumour among the health professionals working in the radiology unit or cardiac catheterisation or other procedures involving exposure to radiation. The first concern was reported by two interventional cardiologists from Canada followed by three physicians who worked with fluoroscopy. Further, four cases were reported in France and Israel with left sided predisposition of brain tumours. In a study with

26 cases, 22 displayed left-sided brain tumour, which was uncommon among the general population. In a similar study with 11 cardiologists involved in invasive procedures, the exposure to radiation was higher in the outside left and outside centre than the right which was probably due to the use of safety caps (4).

Eye problems: Incidence of cataract and lens opacity was noted among the health care providers conducting invasive procedures. The International Protection for Radiation Protection reviews the dosage for the eye with a threshold of 0.5Gy for the lens and limits the dosage from 150mSv year-1 to 20mSv in a year in an average of 5 years and nor exceeding 50mSv a year (6).

Thyroid disease: The exposure of the thyroid gland to ionizing radiation increases the chances of thyroid cancer among children and adolescents more than the adults. The thyroid gland is extremely sensitive towards radiation with radiation being the most important cause of changes in the thyroid gland (3). The risk of thyroid cancer increases with exposure to mean dosage of 0.05 to 0.1 Gy. Further, the risk also decreases with increasing age. Children are more susceptible to thyroid cancer than the adults (7).

Cardiovascular effects: Ionizing radiation has a greater effect on the health of a patient. Various studies have shown that patients with cancer are treated with high doses of radiation and are at great risk for development of cardiovascular complications in the later stage of their life (8). According to a research study conducted in 1984, it was revealed that mediastinal radiotherapy in Hodgkin's disease caused 25% of deaths which were not associated with the actual disease condition. The heart can tolerate minor radiological exposures. Ablation of atrial fibrillation using X rays has been reported though the injury to the surrounding tissues has not been mentioned. It was observed that the radiation caused fibrosis and inflammatory infiltration. The injury caused by radiations may take a long time to manifest and heal leading to further complications (9).

Reproductive system effects: Effect of radiation on the reproductive system may be fatal and linked with the other systems. Radiation above prescribed dosage may affect the tissues and the organs. The effect of radiation on the central nervous system may cause a delay in the onset of puberty. It may also cause hyperprolactinemia or gondotropin deficiency. Irradiation of the testes in low doses may affect the germinal epithelium. Doses above 0.35Gy may cause aspermia, which may be reversible. Dosage above 2Gy may cause irreversible damage to the testes causing irreversible aspermia. A dose of 4Gy may cause sterility in 30% of females among young women while 100% among women above 40 years. The uterus may fail to expand during pregnancy and also lead to premature labour and miscarriages due to the effect of radiation (10).

Adverse effects of radiation exposure

The adverse effects of radiation exposure can be classified into stochastic effect and deterministic effect (non-stochastic effect). Providing an effective dose of radiation reduces the effects of stochastic effect while an equivalent dose reduces the detrimental effect, thus avoiding tissue reactions leading to prevention of various complications. The deterministic effect may be described under dose exposure classified as fluoroscopic time, Cumulative air kerma and dose-area product [Figure 1(4)].

Stochastic effect: According to ICRP-26, stochastic effect means an effect of random or statistical nature. The stochastic effects are the outcome of exposure to radiation causing injury to a single cell or a tissue. The resultant may be direct harm to the affected individual causing neoplasm or chromosomal mutations or mutations of the reproductive cells causing a heritable disease in the progeny (11).

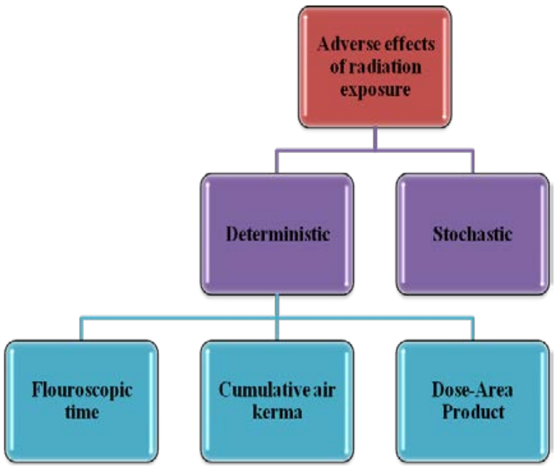

Figure 1: Flowchart showing the adverse effects of radiation exposure

Deterministic effect: It is the dose-dependent effect of radiation with a threshold (4). The deterministic or non-stochastic effect is the effect caused by the radiation therapy with a number of preceding events. The stochastic effect is explained as the damage to a large number of cells randomly, while the clinically observable features with a series of the process give rise to the non-stochastic or deterministic effects. The severity and the probability of the occurrence of the condition such as skin injury, cataract, brain injury or infertility may be considered as the preceding effects and the effect could be determined by the effect of the radiation (11). The occurrence of skin injury can be a result of the prolonged duration of radiation and exposure can be a deterministic effect (4). Dose exposure may be further explained by:

Fluoroscopic time: It is the time duration of fluoroscopy, which does not include cine acquisition imaging.

Cumulative air kerma: It is the X-rays delivered to the skin of the patient or the interventional reference point and is 15 cm from the isocenter from the direction of the focal spot. This is often considered affecting the skin, which is a deterministic effect.

Dose-area product: It is referred to the combination of instantaneous air kerma and the area of the X-ray field. The dose area product determines the dose administered to the patient and indicates the stochastic effect caused due to the radiation.

Radiation protection in interventional radiology

Radiation protection is essential and measures must be taken in every circumstance to protect the patient and health professional to safeguard against the detrimental effects of radiation. There are various imaging techniques which provide accurate results such as MRI, Computed Tomography, and Duplex Imaging. The endovascular procedures are also widely used, which exposes the patient and the radiology technician to large doses of radiation. It may cause cell damage, oxidative stress leading to damage to the chromosomes, thus increasing the risk of development of carcinomas (12). There are various techniques which help in the protection of radiation.

Use of dosimeters: Limiting the dose of radiation helps the occupationally exposed individuals (OEI) to limit the exposure to radiation to a minimum or in limits. Every OEI must be monitored frequently to explore the levels of exposure to radiation (12).

The ICRP has recommended the use of 2 dosimeters to monitor the levels of radiation. One dosimeter must be placed inside the apron and the other one outside the lead apron, at the collar level [Figure 3(13)]. The dosimeter placed inside would be meant for personal protection [Figure 2] (14)]. Frequent monitoring of individuals would help in knowing the levels of exposures and planning other efficient techniques to reduce exposure to radiation. Additional dosimeters may be also used to measure hand doses. For pregnant workers, the dosimeter must be placed under the lead apron near the abdomen, to measure the foetal exposure to the radiation (15).

Figure 2: Personal dosimeters

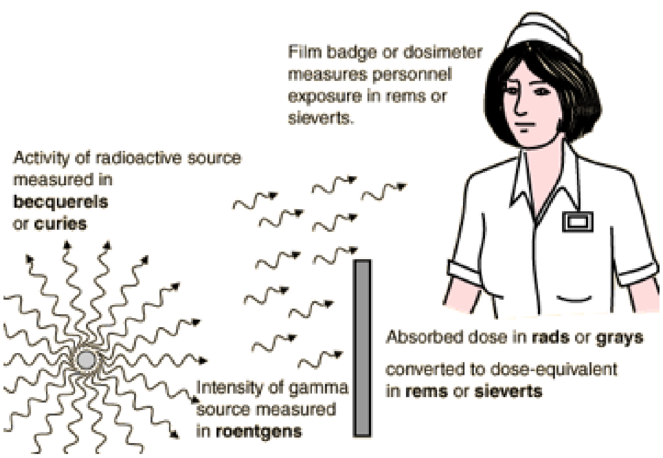

Figure 3: Functioning of outside dosimeters

Dose limits: The effective doses or equivalent doses are defined by the ICRP which are optimal for the individuals exposed to the radiation. The effective dose is meant for the person exposed to the radiation for the procedure while the equivalent dose is for certain parts of the body, tissues or organs of the health professional. According to the ALARA principle of radiation protection, the effective dose for the eye lens is 20 mSv per year at an average of 5 years with not exceeding more than 50 mSv in a single year. Similarly, the effective dosage limit for the skin and extremities is 500 mSv per year. For the health professionals, the least possible dosage is recommended (12). In most of the countries, the limit set by the ICRP is used. The European Union has defined the limit for occupational dose as 20mSv per year over five years with not exceeding 50mSv in a single year, which is similar to the limit set by ICRP. Germany has established a limit of 400 mSv for a lifetime. For pregnant women health workers, the limit must be established as per the general population. According to the National Council on Radiation Protection and Measurements (NCRP) in the US the monthly limit for the embryo or growing foetus is 0.5 mSv. Workers with a reading of <0.1 mSv are within the effective range of ICRP and NCRP guidelines (15).

Prevention from exposure to scatter radiation

Scatter radiation is a secondary radiation when the functional or useful beam interrupts and changes its way leading to scattering of the rays(16). It takes place when the radiation deflects from the source and travels in other directions from the source. The scatter occurs mainly in three ways. The patient is the main source of radiation to the health professionals during scattering radiation. In the first type, the scatter occurs when the rays rebound from the body of the patient. Backscatter occurs behind the X-ray film and the rays travel backward to the X-ray tube. The side scatters result from the objects in the room such as the walls, table, chairs, and floor [Figure 4(17) (18)].

There are several ways to protect from scatter radiation. The design of the room must be made to minimise scatter. A protective shield or curtain must be placed behind the radiation source to minimise the scatter. Protective clothing such as a lead apron may be helpful in minimising the absorption of the rays and provide protection to the staffs (15). An appropriate education about the risks of radiation exposure and the ways to prevent the risks must be provided to every healthcare personnel working with interventional radiation (18). To minimize the radiation exposure to the patient and the operator radiation must only be used on indication. Fluoro-save must be used in place of cineangiography as flouro-save has <10% of radiation exposure of that of cine. Avoiding steep angles reduces the risk of scatter. The left anterior cranial projection must be avoided.

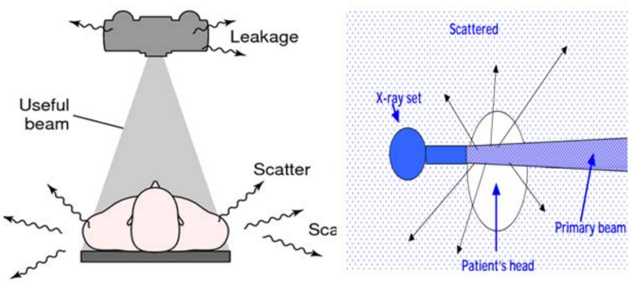

Figure 4: Scatter radiation

Instead of using the magnification mode, placing the detector close to the patient's body minimises the risk of scatter. Reducing the frame rate from 15 frames to 7.5 frames/second with a low dose fluoroscopy mode reduces the exposure to radiation by 67%. Using collimation is often advisable and kept in a view**,** adequate for the coronary procedures (4,15) **[**Figure 5(4)].

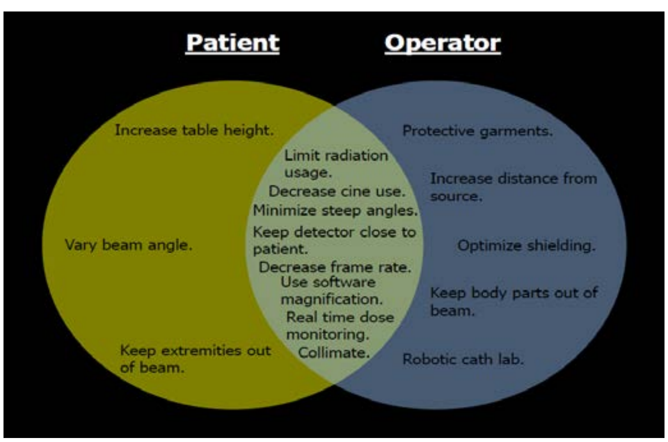

Figure 5: Methods of radiation protection

An adequate shield can minimise the amount of radiation affecting the individual. A 0.5mm lead is known to absorb almost 98% of lead. Additional shields such as radiation absorbing pads, external body shields, barriers, vertical extensions may provide added protection. The garments and barriers protect against scatter radiation while direct radiation is more harmful. The bare parts of the body such as hands, legs and the head are highly susceptible to radiation injury(4,5). Leaded gloves may prevent the hands from scatter radiation although may increase the risk of radiation injury from direct rays. As the rays cause irreversible changes in the eye lens leading to cataract, protective eyeshield such as leaded glasses or a 180^0 helmet may be used to prevent radiation harm. Female patients can be provided with a leaded snug fit garments with breast shield or full chest coverage garments may present the breast and axillary region(5) [Figure 6(4)]. Recently Radpads shields are used to prevent damage caused by scatter rays. Radpads are non-lead radiation protection drapes, which reduce the radiation exposure to a less complicated level (19).

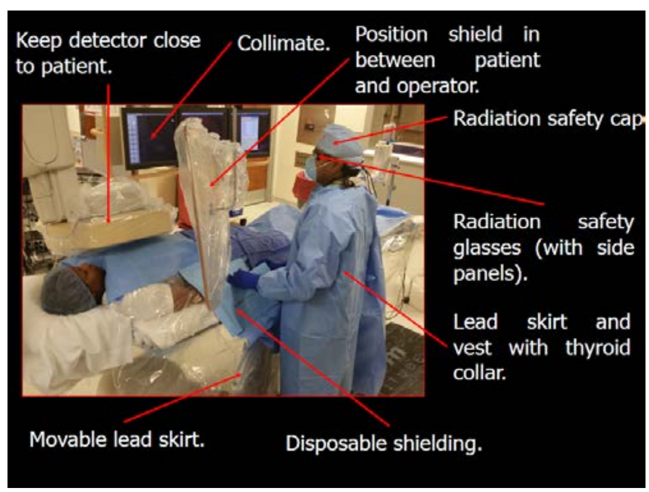

Figure 6: Tools used for minimizing radiation exposure

Education

Adequate education and training are necessary to minimise the risk of radiation exposure. Insufficient knowledge may cause inefficiency in making appropriate decisions and lack of confidence in providing care and carrying over interventional procedures. Most of the radiation hazards are preventable with the utilization of apposite safety measures (5). For safe operating practices, the training of the healthcare staffs in relation to radiation protection is essential. Adequate training will help to increase the awareness about radiation protection and curtail the dose of radiation. According to various research studies, it was observed that appropriate training to the healthcare providers reduced the dose area product, fluoroscopy time and the radiography frame. This also reduced the radiation dose and minimised the exposure to the rays. The real effective dose was reduced by the end of the given study. The European Commission and the Joint Commission on the Accreditation of Healthcare Organizations (JCAHO) recommended training of healthcare professionals with training programs and specific learning objectives for 2-20 hours period.(20).

Conclusion

X-rays or fluoroscopy are although difficult to reflect, they scatter once they come in contact with an obstacle. The obstacle might be a patient or a thing. The hazards of the direct radiation and the scatter are experienced by various interventional cardiologists, radiologists. healthcare professionals and patients. The inappropriate exposure of an individual to radiation can cause skin disorders, nausea, rashes, cardiovascular issues, problems associated with the thyroid gland, eyes, and neoplasms. It may also cause mutation in the chromosomes causing hereditary disorders or genetic birth defects. A high acute dose may also lead to deaths. Adequate protection against the radiation hazards is an essential component in interventional radiation. Use of protective clothing, shields, monitoring instruments and barriers help in minimising the radiation effects. In addition to these, the dose of the X-rays helps in minimising the dosage. Additionally, suitable training programmes for all the levels of staffs including the management would help in the protection of the staffs and the patients against the exposure to the harmful rays thus, safeguarding them against the hazards.

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