Life Safety and Security

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Health Security

Commentary

RADIOPROTECTION IN 2018: AN UPDATE

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Received: June 06th, 2018
Revised: June 09th, 2018
Accepted: June 10th, 2018

Abstract
Fluoroscopically-guided interventional procedures are performed in large numbers in Europe and in the United States. Radiation doses received by interventional radiologists can vary for the same type of procedure and for similar patient doses. Occupational radiation protection is a necessity whenever radiation is used in the practice of medicine. The International Commission on Radiological Protection is engaging against occupational radiation damages, publishing regular recommendations on dose limits. These limits are expressed as effective doses for the whole body and also as equivalent doses for particular regions or tissues of practitioners' bodies. Shielding and personal protective clothes are the most common tools for radiation protection employed up to now. Radiation protection is a dynamic field. It has undergone a significant evolutionary period during the past few decades and general improvement of protection techniques and technology is expected to continue. Further progress in the application of protection principles and concepts will contribute to balanced protection.

Key words: embolization; interventional radiology; minivasive procedures; surgery.

Introduction

Fluoroscopically-guided interventional procedures are performed in large numbers in Europe and in the United States. The number of procedures performed annually throughout the world has increased over the past 20 years (1). The benefits of interventional radiology for patients are extensive and beyond dispute, but many of these procedures have also the potential to produce radiation doses high enough to cause radiation effects in patients and concerns for interventional radiologists (1-4).

Radiation doses received by interventional radiologists can vary by more than an order of magnitude for the same type of procedure and for similar patient doses (4). Recently, there has been particular concern regarding the effects of occupational doses to eye lens in interventional radiologists (2). New data from exposed human populations suggest that lens opacities (cataracts) occur at doses far lower than those previously believed to cause cataracts (5,6). Statistical analysis of available data suggests absence of a threshold dose, although if one dose exist, it is possible that it is less than 0.1 Gy (7,8). Additionally, it seems that the latency period for radiation cataract formation is inversely related to the radiation dose (5).

Occupational radiation protection is a necessity whenever radiation is used in the practice of medicine. It is especially important for image-guided medical procedures (4,9). These procedures may involve high radiation dose rates in the interventional laboratory (10,11). Occupational radiation protection is necessary, not only during fluoroscopically guided procedures but also during computed tomography (CT)-guided procedures, including CT fluoroscopy.

CT fluoroscopy is not really fluoroscopy at all. It differs from conventional fluoroscopy in both equipment and technique. The radiation protection concerns for CT fluoroscopy differ somewhat, particularly in terms of avoiding an excessive radiation dose to the interventional radiologist's hands (12,13).

Occupational radiation protection requires both the appropriate education and training for the interventional radiologist and the availability of appropriate protection tools and equipment. Occupational radiation protection measures must also comply with local and national regulations, and should consider the ergonomic detriment caused by personal protective devices (14-16). These rules are necessary for all individuals who work in the interventional fluoroscopy suite. This includes not only technologists and nurses, who spend a substantial amount of time in a radiation environment, but also individuals, such as anaesthesiologists, who may be in a radiation environment only occasionally. All of these subjects may be considered radiation workers, depending on their level of exposure and on national regulations. All workers require appropriate monitoring, as well as protection tools and equipment. They must also receive education and training appropriate to their jobs (14). The level of training should be based on the level of risk. Radiation workers may know that occupational radiation protection is a priority as is the protection of the patient. In this brief basic review, advices and guidance to interventional radiologists who perform radio-guided procedures and their staff, are provided.

Scattered radiation

For interventional radiologist and for the operating room personnel the main source of radiation is the patient.

X-ray tube is the true source of radiation, but the interaction of the primary X-ray beam with the patient's body produces scattered radiations that emanate in all directions. Balter et al. showed that the intensity of scattered radiation is higher in regions below the table height; in this way, shorter interventional radiologists will receive more scattered radiation than taller (17,18).

The intensity of scattered radiation is determined by many factors such as patient size, angle of the image acquisition system, methods of fluoroscopy and it depends greatly on the total amount of radiation administered to the patient. For this reason, radiologists should always follow the ALARA principle ("as low as reasonably achievable") to achieve the required medical outcome (19). Fortunately, modern equipment offers good image quality, thereby reducing the number of radiological image acquisitions needed. Furthermore for all medical imaging procedures, there are three basic principles: justification, optimization, and dose limits (20). The respect of these basic principles might be beneficial in reducing patient and staff exposure to ionizing radiations.

International Commission on Radiological Protection (ICRP) recommendations

Radiation effects are cumulative and a definitive cell damage can have negative impacts on health. Radiation provokes oxidative stress, which can cause molecular and genetic damage, and this can have serious consequences over time, such as the development of dermatoses, cataract, haematological disorders and even cancer (1,2,21).

ICRP is engaging against occupational radiation damages, publishing regular recommendations on occupational dose limits. These limits are expressed as effective doses for the whole body and also as equivalent doses for particular regions or tissues of practitioners' bodies and are accepted by most countries. The limit for the effective dose is 20 mSv per year (as an annual average over 5 years). The effective dose may not exceed 50 mSv in any single year. The limit for extremities and the skin is 500 mSv per year (22,23). The limit for the lens of the eye is 150 mSv per year but the authors suggest that does not exist a limit dose for radiation cataract formation and, if one exist, it is less than 0.1 Gy (5-8). Table 1 summarizes limits for effective absorbed doses. Despite the ICRP recommendation, there are slightly difference between European Union and the United States. Furthermore, dose limits in European Union can be different from each Country to the other (24).

For estimating effective and equivalent dose, the ICRP recommends the use of two dosimeters: one under the apron, positioned just upon the chest, and the other outside the apron, at shoulder or collar level. Additional dosimeters such as ring or bracelet dosimeters, can be used to measure doses in eyes and in the upper extremities; in this case, the dosimeter should be positioned at the hand that receives the highest exposure (not

Table 1. Recommended dose limits for occupational exposed individuals (adapted from ICRP) (International Commission on Radiological Protection) (15)

Type of limit	Occupational dose limit
Effective dose	20 mSv per year, averaged over defined periods of 5 years[a]
Annual equivalent dose in:	
Lens of the eye	150 mSv[b]
Skinc	500 mSv
Hands and feet	500 mSv

[a] With the further provision that the effective dose should not exceed 50 mSv in any single year; [b] This limit is currently being reviewed by an ICRP Task Group; [c]Averaged over 1 cm2 area of skin regardless of the area exposed.

necessarily in the dominant hand) (10,22).

An important problem in individual monitoring is the poor compliance of the occupationally exposed individuals; in fact, they sometimes do not wear dosimeters, for simply negligence or to ensure that results remain below the threshold, in order to avoid administrative investigations (25).

Tools for radiation protection

Tools for radiation protection can be divided in two main categories: shielding (equipment mounted and protective patient drapes) and personal protective clothes.

Equipment-mounted shielding includes protective drapes suspended from the table and from the ceiling.

Under the table scattered radiations are higher, for this reason table-mounted shields, between the X-ray tube and the worker, are very important because provide additional shielding to lower extremities. Sometimes a protective screen cannot be deployed for clinical reasons (for example if the C-arm is in a steep oblique or lateral position).

Ceiling suspended shields, generally made from transparent leaded plastic, significantly reduce doses to the upper part of the body, head and particularly to the lens of the eye (26,27). Protective patient drapes are attenuating drapes that contain metallic elements (bismuth or tungstenantimony), placed on the patient after that the operative site has been prepared. The authors show that these devices allow a great reduction of operator's dose (reductions of 12-fold for the eyes, 26-fold for the thyroid, 29-fold for the hands) (28). A further option available for additional protection is the use of mobile protective screens but these are uncomfortable because they don't allow the worker to stay close to the patient and often cannot be used.

Several personal protective devices are available, such as aprons, goggles, thyroid shields, eyewear and gloves. Aprons, goggles and thyroid shields are the principal radiation protection tools and they always should be worn.

Because cataract induction may be a stochastic effect, it is advisable to wear leaded eyeglasses with large lenses and protective side shield particularly when ceiling suspended shields are not available.

The best solution to protect the operator's hands is to maintain hands in the direction of the beam for as short time as possible. Lead gloves do not provide protection when the hands are under the radiation beam, indeed their use can increase radiation dose to the hand (29). It could be for three reasons: because there is an automatic increased dose of radiation when any shielding is placed into the primary beam, because there is a greater production of scattered radiation and because the false sense of security that these gloves provide can lead the operator to be less cautious.

A trick for radiation protection

We suggest a simple method that could have a significant role in reducing the radiation dose of interventionists' hands. It consists in using a sterile surgical suture through the suture eye of the vascular catheter introducer, in order to secure the sheath to the skin. In this manner, the operator's hand can be kept out of the primary radiation beam during wires and endovascular catheters retraction. For this purpose, Zeinali-Rafsanjani et al. suggest the use of a sterile catheter fixation tape (30) but, in our experience, the tape could loose its adhesion when it is wet with blood, contrast or saline.

Conclusions

The conservative concepts and models used today provide a suitable basis for achieving adequate protection. The standard of radiation protection across the developed area appears good and sometimes excellent. A similar conclusion can be drawn for some, but not all, countries throughout the rest of the world.

However, radiation protection is a dynamic field. It has undergone a significant evolutionary period during the past few decades and general improvement of protection techniques and technology is expected to continue. Further progress in the practical application of protection principles and concepts such as optimization and dose constraints will contribute to balanced protection. In addition, much is going on in fundamental research, particularly in the biology area, which could improve the scientific foundation upon which today's protection is based. Further epidemiology studies might also contribute to this improvement. All of this could lead to more efficient use of resources allocated to protection, as well as other benefits.

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