Radiation monitoring in interventional cardiology: a requirement

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Radiation monitoring in interventional cardiology: a requirement

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Abstract. The increasing of procedures using fluoroscopy in interventional cardiology procedures may increase medical and patients to levels of radiation that manifest in unintended outcomes. Such outcomes may include skin injury and cancer. The cardiologists and other staff members in interventional cardiology are usually working close to the area under examination and they receive the dose primarily from scattered radiation from the patient. Mexico does not have a formal policy for monitoring and recording the radiation dose delivered in hemodynamic establishments. Deterministic risk management can be improved by monitoring the radiation delivered from X-ray devices. The objective of this paper is to provide cardiologist, techniques, nurses, and all medical staff an information on DR levels, about X-ray risks and a simple a reliable method to control cumulative dose.

Introduction

The story began in 1895, when a German physicist discovered a new kind of rays. This is almost 120 years. The medical use of X-ray beam, while offering great benefit to patients, also contributes significantly to radiation exposure of individuals and populations. According to the results published by the United Nations Scientific Committee on the Effects of Atomic Radiation in 2012, interventional procedures contribute only 10% to the frequency of radiation use on the medical field whereas their contribution to collective dose is 19%. The cardiologists and other staff members in interventional cardiology are usually working close to the area under examination and they receive the dose primarily from scattered radiation from the patient. Mexico does not have a formal policy for monitoring and recording the radiation dose delivered in an interventional cardiology laboratory. The objective of this paper is to provide cardiologist, techniques, nurses, and all medical staff the new findings and brings them up a simple a reliable method to control cumulative dose for radiation safety.

Interventional Cardiology

Fluoroscopy is the method that provides real-time X ray imaging that is especially useful for guiding a variety of diagnostic and interventional procedures. Since the early 20th century, fluoroscopy has been integral to the practice of diagnostic radiology [1]. For the most part, fluoroscopic procedures were primarily diagnostic and involved relatively small risks to patients and personnel. However, over the

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past 10–15 years, fluoroscopic procedure mixes have included an increasing fraction that are primarily therapeutic [2]. Thus, radiation exposure is a significant concern for interventional cardiologists and patients due to the increasing workloads and the complexity of procedures over the last decade [3]. Interventional radiology and interventional cardiology (IC) contributes a significant proportion of the collective dose of the population from medical exposures. According to the results published by the United Nations Scientific Committee on the Effects of Atomic Radiation, interventional procedures contribute only 10% to the frequency of radiation use on the medical field whereas their contribution to collective dose is 19% [4]. When complex procedures are performed or procedures are repeated for the same patient, high radiation dose levels can occur because procedures often require long fluoroscopy time and a large number of images.

Radiation effects and humans

Much has been said about the dangers of radiation, and particularly about the role played by diagnostic X-ray radiology, which contributes 99% of man-made radiation exposure to humans [5]. The adverse risks of radiation exposure may be described in terms of stochastic and deterministic effects. The higher dose delivered in IC observes its severity only deterministic effects. It severity is proportional to the dose and the dose exposure is usually described in terms of fluoroscopic time, cumulative air kerma, and dose-area product. In 2011, the ICRP alerted the radiological community to the epidemiological evidence of higher incidence of cataracts in interventional cardiologists [6]. The degree of exposure has been correlated with a linear increase in the development of both benign and malignant thyroid neoplasms, structural and functional changes as a result of radiation exposure have been reported in the thyroid gland [7, 8].

Recognizing radiation injury and effects

The Center for Device Regulation, Radiation Health and Research (CDRRHR)-Food and Drug Administration (FDA) of the Department of Health (DOH) [9] reports the potential effects of prolonged exposure to radiation during interventional fluoroscopic procedures described in Table 1.

TABLE1. Potential effects of X-rays during interventional fluoroscopic procedures

Effect	Single-dose Threshold (Gy)	Onset
SKIN		
Early transient erythema	2	2-24 Hours
Main Erythema	6	~10 d (-1.5wk)
Temporary hair loss	3	~3 wk
Permanent hair loss	7	~3 wk
Dry desquamation	14	~4 wk
Moist desquamation	18	~4 wk
Secondary ulceration	24	>6 wk
Late erythema	15	~8 – 10 wk
Ischemic dermal necrosis	18	>10 wk
Dermal atrophy (1st phase)	10	>14 wk
Dermal atrophy (2nd phase)	10	>1 y
Induration (Invasive Fibrosis)	10	>1 y
Telangiectasia	10	>1 y
Late dermal necrosis	>12?	
Skin cancer	not known	>5 y
EYE		
Lens opacity (detectable)	>1-2	>5y
Lens/cataract (debilitating)	>5	>5y

Radiation dosimetry and principles

Monitoring of the radiation exposure induced by interventional cardiology procedures has become more important due to the rapidly increasing number of X-ray devices in use. Therefore, the dose delivered is not standardized and, in some cases, could reach levels high enough to produce deterministic effects to the patient. Surface determination of the dose is often measured by detector, but, often it is not possible to measure the dose at an organ or tumour directly due the obvious obstacles for introducing dosimeters into the patient. In this case the dose can be calculated taking into account the appropriate models of the anatomy of the patient anatomy as well as the radiation field parameters from measurements on the skin of the patient [10]. In an IC laboratory can be used different dosimetric methods in order to radiation monitoring. In this paper are described some of them. Historically, the first issue to measure radiation dose IC laboratory was radiographic film. X-ray film consists of a base of thin plastic sheet with a radiation sensitive emulsion coated uniformly on one or both sides of the base. Radiographic film finds use in an immense variety of diagnostic, having the advantages of high reliability, versatility and ability to provide a permanent information record. The radiographic film has a working range from 0.01 Gy up to 2 Gy which is rather narrow range that can be exceeded in the highest dose fluoroscopic procedures. Disadvantage, the radiographic film is difficult to measure the absolute of X-ray dose. Traditionally, the ionization chamber (ICH) has been the reference dosimeter for interventional cardiology and can be used for quality assurance and calibration of other dosimeters. The sensible volume of ionization chamber could be 0.6 or 0.18 cc. The range of measurable radiation dose is from 1uGy up to 16kGy. However, inconvenient of IC in clinical practice is it size. The ICH is connected via a cable with an electrometer to make the measure should be used that ensure appropriate levels of accuracy and long term stability. Semiconductor detectors Dosimeters are other detectors proposed for diagnostic measurements [11]. They produce large signals from modest amounts of radiation, they are rigid and do not require pressure correction, which makes them suitable for some clinical applications. The simplest of semiconducting devices is the diode, which based on a p–n junction between the p-type and n-type parts of a semiconductor. As ionizing radiation strikes the semiconductor, electron hole pairs are induced. The diode is more sensitive and has small size compared to ionization chamber. A disadvantage of diode as dosimeter in interventional cardiology is also uses cable. The metal-oxide semiconductor field effect transistor (MOSFET) dosimeter for its an excellent spatial resolution is suggested in diagnostic radiology. The use of MOSFET dosimeter in clinical practice also needs correction factors for energy dependence and field size, this is not tissue equivalent. The MOSFET dosimeter is useful in the range from 1.5 mGy up to 2Gy. Disadvantage of MOSFETD is visible in radiographs and it has temperature dependence [12, 13]. The diamond dosimeter (DD) is other detector can be used to measure equivalent dose in interventional cardiology procedures with a good agreement with IC. DD is suitable for in vivo dosimetry due to its small size, resistance to the radiation damage, and tissue equivalent. However, the use of the diamond for low energy X-ray needs a correction factor another disadvantage is expensive [14]. The most commonly used radiochromic film is the Gaf-Crhomic^{TM} film. Basically, the radiochromic films are rectangular sheets that change color when exposed to a sufficient absorbed dose. Because color indicated cumulative dose, dosimetry is usually qualitative to some extent, which challenges the accuracy of its measurement. Disadvantages, radiochromic film is insensitive to low doses, below 3 Gy, which is an important range for accurate tracking of diagnostic radiation dose [15. A practicable used type of dosimeter in the past and present is the thermoluminescent dosimeter (TLD) [16, 17]. The thermoluminescent dosimeters (TLDs) are based on the physical property of certain crystals to absorbe energy in metastable states that are a result of defects in the material lattice. These trapped electrons or holes remain at the metastable state until they are heated to recombine and emit the energy in the form of light. The quantity of light emitted is proportional to the energy deposited in to the crystal during irradiation. Dosimeters with thermoluminescence and semiconductor detectors are considered here the small size of TL dosimeters (TLDs) allows their application for conducting measurements on patients. TLDs are available in various forms (e.g. powder, chips, rods, ribbons) and made of various materials [18]. Dosimeters most commonly used in medical applications are based on lithium fluoride doped with magnesium and titanium (LiF:Mg,Ti) because of its tissue equivalence (Z_{eff}=8) but other high sensitivity materials such as LiF:Mg,Cu,P; Li2B4O7:Mn; CaSO4:Dy and CaF2:Mn have also been used. It can be used to measure the dose ranging from 10 uGy to 10 kGy [19, 20]. The main disadvantage of these devices has been their energy dependence of response which differs considerably from that of ionization chambers. More recently, optically stimulated luminescent dosimeters (OSLDs) have been adopted for this role. Both types of dosimeters operate by recording an energy reading upon irradiation and emitting an output of the recorded dose upon appropriate stimulation. TLDs require a heating stimulus to produce readouts of their recorded doses while OSLDs require an optical stimulus, enabling more rapid, accurate, and reproducible measurements [21, 22, 23]. Radiation dosimetry as well as dose distribution for interventional dosimetry purposes has steadily evolved over the last few decades with the introduction of various new detectors. Concerning quality assurance, The Society of International Radiology Standards of Practice Committee guidelines for establishing quality improvement program in interventional radiology [24]. The quality assurance (QC) of diagnostic X ray beams in IC is fully characterized by their spectrum as well as X-ray beam parameters: tube voltage, the first and the second HVLs (HVL1 and HVL2), total filtration and their combinations are used for this purpose. A quality assurance program (QAP) for interventional cardiology includes all of the aspects of radiological protection (RP) of patients and staff in addition to the usual clinical aspects. The Working Group on Interventional Cardiology of ISEMIR [25] has produced a set of recommendations for occupational radiological protection and concluded after a wide international survey that the dose received by cardiologists during percutaneous coronary interventions, electrophysiology procedures, and other interventional cardiology procedures can differ by more than an order of magnitude for the same type of procedure and for similar patient doses. Simple methods for reducing or minimizing the occupational radiation dose are included in the recommendations.

Dose reduction

Radiation safety is the concern of all health care providers who perform procedures associated with radiation imaging, whether for diagnostic purposes or therapeutic procedures. Appropriately, there has been increasing public and societal interest in limiting patient radiation. During the last few years, several scientific and professional societies have produced guidelines on radiation safety (including patient dosimetry) for interventional radiology [26]. Some of these guidelines have been adopted simultaneously by American and European interventional radiology societies [24, 25] and others have been produced by groups of experts and later endorsed by professional societies [26, 27, 1]. In order to help in the optimization of the interventional practices. Diagnostic reference levels (DRLs) are still a challenge for interventional radiology. The ICRP proposed their application in interventional radiology in 2009 [5], but it still is a long way to their effective application. The National Council on Radiation Protection and Measurements in the USA has published a document on this issue [6] and the ICRP launched a working party in 2012 to also give more specific advice on the use of DRLs in interventional procedures and new imaging techniques. In a workshop organized by the IAEA in 2010 for pediatric interventional cardiology [24] involving 11 Latin American countries, it was reported that only 64 % of the cardiologists used their personal dosimeters regularly. In Mexico not have a formal policy for monitoring and recording the radiation dose delivered in an interventional cardiology laboratory. To manage the radiation dose, it must be measured. All physicians and staff involved with interventional fluoroscopy must be properly trained on the basic principles of radiation physics and safety. A qualified medical physicist must be involved with the physician in equipment selection and staff education. The best quality image with the most effective radiation dose provides the best patient care.

Future

Concerning the future of interventional cardiology is picts in good chance if form an interventional team group: Cardiologists, medical physics, technician, nurses and industry together commit to clinical care; and work with many other associates with continued cooperative efforts and research to optimization dose. A data base on a real project is necessary to set up and develop acceptable methods for future surveys of population exposure from medical X-rays. Electro technical Commission (IEC), the digital imaging and communications in medicine (DICOM) for radiation dose reporting in radiology and the profiles from form the RIS systems around the country may then be input to databases. Radiation dose data collected by the real-time dosimeter during each intervention is the new generation dosimeter. One of the important initiatives under radiological protection is the SmartCard project, this program was proposed by IAEA [28-33]. The role of dosimetry in diagnostic radiology has to be consistent with the Bonn Call-for-Action proposed during last meeting in 2012. Nowadays, electronic dosimeters are also suggested for personal dosimetry. Education and training programs will be consist in two levels. The first provides recommendations for continuing education and training after qualification and when new techniques are implemented. The second level, specific educational objectives to be included in specific diagnostic area. The program will contain specific topics for radiation dosimetry and radiation protection, recognizing the importance of reducing patient doses while maintaining the desired level of guarantee quality in medical exposures (good therapeutic treatments and images of sufficient quality for diagnosis). I suggest in all ICL an environmental program dosimetry, an estrictic clinical dosimetry and physical dosimetry to maintain radiation doses As Low As Reasonably Achievable (ALARA). The professional works in different establishment of practical radiological sources in the case of ICL to radiation, take account of the relevant recommendations of the international organizations. Patient dosimetry could will be the main topic in the next generations. PD will be the main objective for radiation protection programs. Radiation dosimetry in diagnostic radiology will provide recommendations taking into account diagnostic reference levels (DRL) and it requires acceptable quality dose (AQD) [34-37, 3]. For personal radiation monitoring, I suggest the use of two personal dosimeters for occupational dosimetry interventional cardiology laboratories: one worn on the trunk of the body inside the apron and the other worn outside the apron at the level of the collar or the left shoulder. The dosimeter under the apron provides an estimate of the dose to the organs of the shielded region. The dosimeter worn outside the apron supplies an estimate of the dose to the organs of the head and neck, including the thyroid and lens of the eyes (if unshielded), but greatly overestimates the doses to organs of the trunk.

Conclusion

We are seeing an impressive increase in the use of interventional procedures for more complex procedures and they are being used by more medical specialties owing to the undisputed clinical benefits. However, practitioners, scientists, manufacturers, and regulators have an obligation to promote the best level of radiation safety for patients and staff. For dose optimization a Monte Carlo simulation can be used to estimate the absorbed dose conversion coefficients. Dose determinations should be performed using a calibrated instrument and a dosimetry code of practice such as the one recommended by the IAEA. The assessment of patient dose is an essential aspect of the justification and the optimization process in X-ray diagnostic radiology. Medical physics support is needed for accurate dose determination and for a better understanding of how patient dose is affected in clinical practice by examination protocols and exposure parameters. A training program is an essential part of the dose reduction for the interventional cardiology laboratory. A team collaborative effort involving physicians, staff, medical or health physicists, quality assurance personnel, and hospital administration. Interventional cardiologists are an essential part of this process and need to ensure the best possible outcomes for ourselves and for our patients.

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