WORLD JOURNAL OF PHARMACEUTICAL RESEARCH
SJIF Impact Factor 6.805
Volume 5, Issue 12, 1167-1179. Research Article ISSN 2277– 7105

RADIATION EXPOSURE TO CATH LAB PROFESSIONALS DURING DIFFERENT CARDIAC CATH PROCEDURES

Masroofa Syed(MSC)[1], Tantry Tariq Gani(MD)[2], Imran Hafeez(MD,DM)[1], Farooq Ahmad Ganie(MS,Mch)*[3], Mohd Iqbal Dar(MD)[1] and Nissar Ahmad Tramboo(MD,DM)[1]

Department of Cardiology[1], Anesthesiology and Critical Care[2] and Department of Cardio Vascular and Thoracic Surgery[3] Sher-i-Kashmir Institute of Medical Sciences, Soura Srinagar, Kashmir India.

Article Received on
21 Oct. 2016,

Revised on 11 Nov. 2016,
Accepted on 01 Dec. 2016

DOI: 10.20959/wjpr201612-7486

***Corresponding Author**
Dr. Farooq Ahmad Ganie
Department of Cardio Vascular and Thoracic Surgery Sher-i-Kashmir Institute of Medical Sciences, Soura Srinagar, Kashmir India.
farooq.ganie@ymail.com

ABSTRACT

Background: Many cardiac procedures can deliver high radiation doses to the clinical staff. This exposure may represent a significant health risk, resulting in deleterious clinical implications which can affect not only the personnel involved, but also their progeny. Radiation injuries have occurred as a result of prolonged interventional procedures with fluoroscopy times more than 30 minutes. Therefore safety of the patient and operator became utmost important. ***Methods***: For a total of 200 patients undergoing different cardiac procedures, radiation exposure of cath lab professionals was recorded using the pocket dosimeters, calibrated from Atomic Energy Regulatory Board (AERB), accredited secondary standard dosimetry lab (SSDL). The radiation dose to the cath lab workers was obtained and recorded per procedure. Dosimeter readings in terms of exposure in milli Roentgens(mR) was converted to effective dose to the person as suggested by International Commission on Radiological Protection (ICRP) i.e. milli Seivert (mSv). The results obtained were compared with the limits of effective dose, set by the commission using standard methods of statistics. ***Results:*** It was observed that the average fluoro time for PTMC was maximum of 40 minutes, for PVBD; 33 minutes, for CAG+PCI; 33 minutes, for PCI; 30 minutes, for PPM 18; minutes and for CAG, it was about 8 minutes. It was reported that the interventionalist I.e. primary operator received the whole body dose; maximum of 0.25 mSv and minimum of 0.08 mSv in PTMC, in CAG + PCI, maximum of 0.2 mSv & minimum of

0.08 mSv, in PCI, maximum of 0.18 mSv & minimum of 0.07 mSv, in PVBD, maximum of 0.1 mSv & minimum of 0.03 mSv, in PPM, maximum of 0.08 mSv & minimum of 0.03 mSv and in CAG, maximum of 0.05 mSv & minimum of <0.01 mSv. The secondary operator received the following whole body radiation dose; in PTMC maximum of 0.18 mSv and minimum of 0.06 mSv, in CAG + PCI, maximum of 0.1 mSv & minimum of 0.03 mSv, in PCI, maximum of 0.11 mSv & minimum of 0.025 mSv, in PVBD, maximum of 0.08 mSv & minimum of 0.02 mSv, in PPM, maximum of 0.05 mSv & minimum of 0.01 mSv and in CAG, maximum of 0.03 mSv & minimum of <0.005 mSv. The whole body radiation doses for the Technologist and the Nurse were approximately same; in PTMC, maximum of 0.06 mSv & minimum of 0.03 mSv, in CAG + PCI, maximum of 0.07 mSv & minimum of 0.03 mSv, in PCI, maximum of 0.05 mSv & minimum of 0.02 mSv, in PVBD, maximum of 0.03 mSv & minimum of <0.01 mSv, in PPM, maximum of 0.02 mSv & minimum of <0.01 mSv and in CAG, maximum of 0.015 mSv & minimum of <0.005 mSv respectively. ***Conclusion:*** that radiation dose is directly proportional to fluoro time and the primary operator, who is solely handling the procedure receives the maximum whole body radiation dose in all the cath lab procedures. In our study, we found an increased radiation exposure using radial technique compared to femoral technique. A protective device could help to decrease this.

KEYWORDS: primary operator, Fluoro time, Radiation dose.

INTRODUCTION

Over the last 30 years, medical cardiology imaging has rapidly grown, becoming an essential part of the cardiology clinical practice. Imaging procedures including conventional imaging tests such as echocardiography, radionuclide imaging and angiography as well as newer Imaging techniques such as computed tomography, magnetic resonance imaging and PET hold a promise to expand diagnostic capabilities.[1] These techniques widely differ not only for what concerns costs, availability and technical information, but they also differ in environmental and health hazards. Many cardiac procedures can deliver high radiation doses to the clinical staff.[2] This exposure may represent a significant health risk, resulting in deleterious clinical implications which can affect not only the personnel involved, but also their progeny.[3-5] Unfortunately, many physicians are unfamiliar with radiation biology or the quantitative nature of the risks associated with ionizing radiation.[6-9]

Interventional procedures constitute only 12% of all radiological procedures but contribute to about 48% of the total collective dose per head in the adult cardiological patient.[10] This value is steadily increasing. In Europe number of arteriography and interventions performed annually were 350,000 in 1993 and > 1 million in 2001.[11] On average, a left ventriculography and coronary angiography correspond to a radiation exposure of about 300 chest X-rays; a coronary stent to 1,000; a peripheral artery intervention to 1,500-2,500; and a cardiac radiofrequency ablation to 900 up to several thousand.[12-16] Although there is a general appreciation that radiation by itself is certainly not a good thing for the patient or the operator, radiation safety is rarely much of an overt concern to interventionalist.[17] Occupational doses in interventional procedures guided by fluoroscopy are the highest doses registered among medical staff using X-rays.[18]

Radiation used in catheterization laboratory is x-rays. X-rays beam is a stream of particles; each contains defined amount of energy. Each X-ray photon contains thousands of times the energy of a photon of visible light. This quality of X-ray is due to its very short wavelength and very high frequency.[19, 20, 21] Radiation injuries have occurred as a result of prolonged interventional procedures with fluoroscopy times more than 30 minutes. Therefore safety of the patient and operator became utmost important.[22-24]

There are two main biological effects of radiation (table 1): tissue reactions (deterministic effects), which happen when the radiation dose exceeds a specific threshold and become evident days to months after exposure as they cause a predictable change in tissue and stochastic effects, which relate to the potential for future harm to the tissue and the body.[25] Tissue reactions of most concern for patients and operators include skin injuries (reported in patients undergoing long, repeated and complicated interventional procedures and cataract (present in one-third to half of interventional cardiologists or radiologists.[26,27] The stochastic effect of most concern is a carcinogenic effect. It occurs when the cell is modified by damage to its DNA but remains viable, the harm eventually being expressed through cell proliferation.[28]

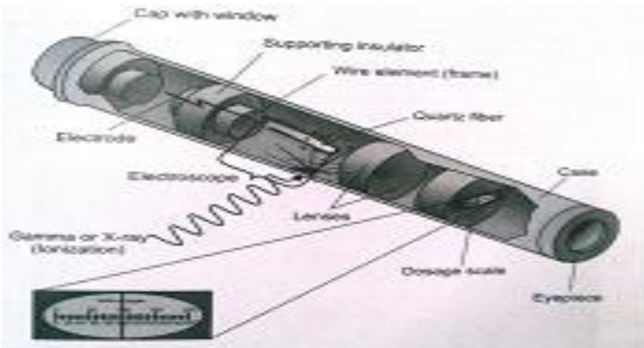

Fig. Pocket dosimeter.

In this study, we have assessed whole body radiation doses of cath lab professionals for different procedures based on different fluoro times for a period of six months using direct reading dosimeters (DRD) of ionization type i.e. pocket dosimeters. A pocket dosimeter is a direct reading device in which there are two quartz fibers, suspended within air filled chamber, on a wire frame (figure). It has a built in capacitance which can be charged by an external potential (charger). The positive charge is placed on the wire frame, by means of the charger. The quartz fiber is bent away from the frame due to columbic repulsion. This can be visible through an optical lens system upon which an exposure scale is superimposed.

These dosimeters should be fully charged prior to their use so that the initial reading of the dosimeter is set at zero. When exposed to radiation, ion pairs are produced in the air. These ion pairs partially neutralize the positive charge, reducing the columbic repulsion and allowing the fiber to move. Hence, the quartz fiber moves closer to the wire frame that can be seen as down range excursion of the hair line fiber on the exposure scale (graticule). The movement of the quartz fiber is proportional to the radiation exposure, which is measured in Roentgen (R). The Roentgen is the unit of exposure = 2.58×10^{-4} C/Kg. The dose in air can be calculated from the exposure, where 1R exposure is equal to 8.76mGy (0.876 rad) of air dose. The dosimeter is available in different ranges varying from 0-200 mR, 0-500mR, 0-5R, 0-20R, 0-200R and 0-500R for measurement of X and gamma rays. It can detect photon energies from 20 KeV-2 MeV. For personnel monitoring, smallest range (0-200 mR) should be employed. In this study, smallest range dosimeter i.e. 0-200 mR was used for personnel monitoring of whole body radiation exposure.

Cardiac catheterization protocol

The catheterization team usually consists of a primary operator, performing the catheterization, one sterile secondary operator (assistant), one or two circulating assistants, an anesthesiologist for airway management if need arises, two technologists, a nurse and personnel behind lead glass walls. All personnel in the vicinity of the patient wear lead aprons (0.5 mm lead equivalent). Thyroid collars and lead eye glasses are also required. Most of the time a lead glass screen is used, positioned aside the patient table between the cardiologist and the patient. Hemi axial views are obtained with the rotations and angulations of the C-arm. The purpose of this study was to **a**ssess the whole body radiation exposure received by the professional cath lab staff during different cath lab procedures.

By Monitoring the whole body radiation exposure of all cath lab professionals in MilliRoentgens (mR)/person per procedure, Recording the data of whole body exposure levels, Converting the whole body exposure to whole body radiation dose in milli Seivert (mSv)/personm and analyzing the data and assessing the results.

And to analyze the differences in radiation exposure from different cardiac cath lab procedures, focusing on impact to the operator and aimed at developing radio protective devices.

MATERIAL AND METHODS

This study was conducted in tertiary care hospital Sher-i-Kashmir Institute of Medical Sciences Srinagar (SKIMS) in the department of cardiology. It was an open prospective, non-randomized, observational study carried out from March'2015 to August' at SKIMS, Cardiac Catheterization Laboratory. The study included patients taken for elective CAG, elective CAG and PCI, elective PCI, rescue PCI, PPM, PTMC and PVBD. Data was collected for six different types of procedures: Coronary angiography (CAG); Coronary angiography + Percutaneous coronary intervention (CAG+PCI); Percutaneous coronary intervention (PCI); Permanent pacemaker (PPM); Percutaneous transluminal mitral commissurotomy (PTMC) and Pulmonary valve balloon dilatation (PVBD).

Exclusion criterias

Age less than 15 years old.

Pregnant.

Active bleeding or high risk of bleeding (severe hepatic insufficiency, active peptic ulcer disease, creatinine clearance <30mL/min, platelet count <100,000 mm^3).

Uncontrolled hypertension (persistent systolic blood pressure >180 mm Hg).

Cardiogenic shock.

The study was performed using victorean pocket dosimeters, worn at chest level over the lead apron. For a total of 200 patients undergoing different cardiac procedures, radiation exposure of cath lab professionals was recorded using these pocket dosimeters, calibrated from Atomic Energy Regulatory Board (AERB), accredited secondary standard dosimetry lab (SSDL). The radiation dose to the cath lab workers was obtained and recorded per procedure. Dosimeter readings in terms of exposure in milli Roentgens(mR) was converted to effective dose to the person as suggested by International Commission on Radiological Protection (ICRP) i.e. milli Seivert (mSv). The results obtained were compared with the limits of effective dose, set by the commission using standard methods of statistics.

RESULTS

Fig 1: Average Fluoroscopy time (in mins) for different CATH Lab procedure.

Procedure	Fluoroscopy time (min)		Radiation dose (mSv/person)							
			Primary operator		Secondary operator		Technologist		Nurse	
	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max
CA	2	12	<0.01	0.05	<0.005	0.03	<0.005	0.015	<0.005	0.015
CA + PCI	12	45	0.08	0.2	0.03	0.1	0.02	0.08	0.02	0.05
PCI	14	46	0.07	0.18	0.025	0.11	0.02	0.06	0.02	0.05
PPM	9	26	0.03	0.08	0.01	0.05	<0.01	0.02	<0.01	0.02
PTMC	20	60	0.08	0.25	0.06	0.18	0.03	0.07	0.02	0.06
PVBD	15	50	0.03	0.1	0.02	0.08	<0.01	0.03	<0.01	0.02

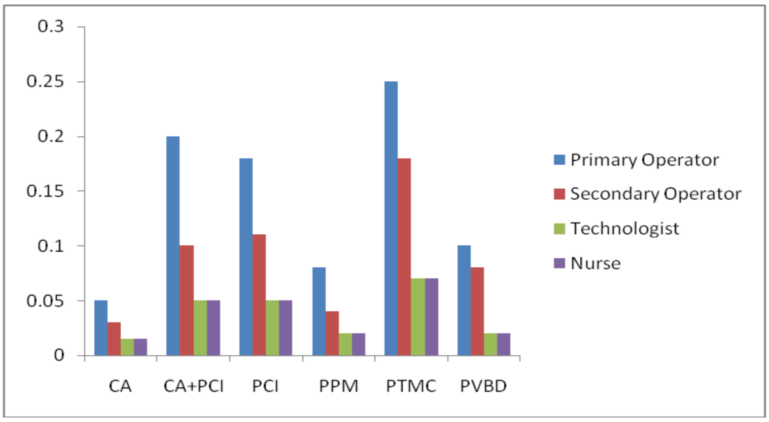

Fig 2 Whole body dose (in mSv/person) to cardiac CATH lab professionalsl for different procedures

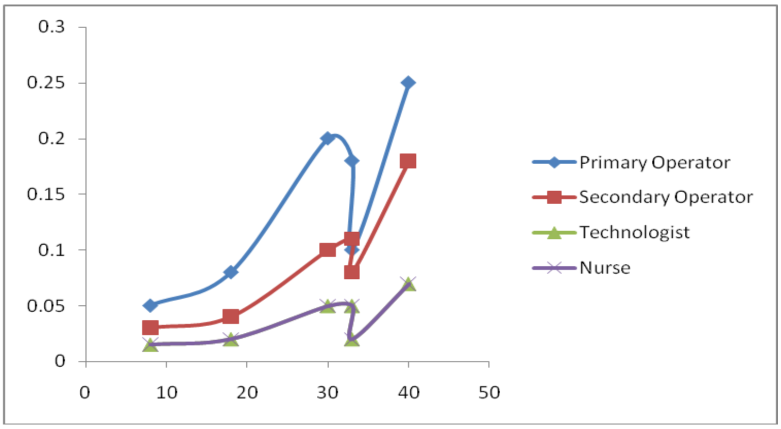

Fig 3 Relation between radiation dose received by cath lab personnels and fluoroscopy time.

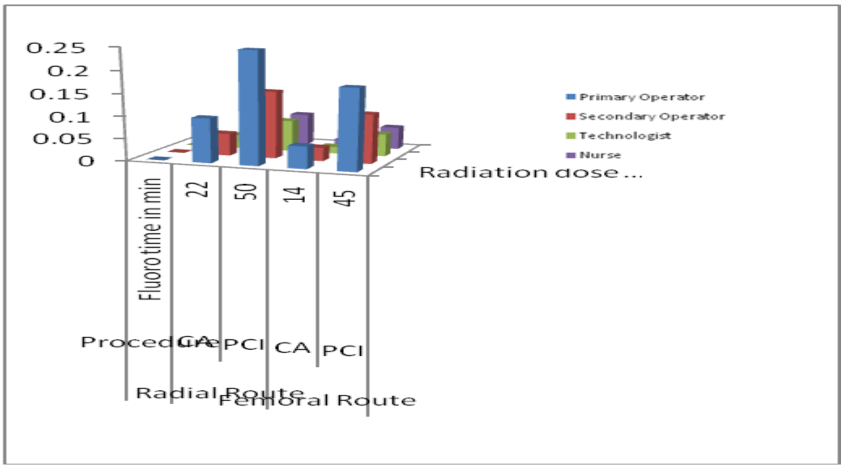

Fig 4 Radial route Vs Femoral route for coronary angiography and percutaneous coronary intervention.

The whole body dose analysis of different cardiac catheterization laboratory professionals of SKIMS was done using pocket dosimeters of ionization type, calibrated from Atomic Energy Regulatory Board (AERB) accredited secondary standard dosimetry lab (SSDL). The whole body radiation dose in mSv was recorded for cardiac interventionalist (primary operator), assistant interventionalist (secondary operator), technologist and nurse for about 200 procedures (n=200), over a period of six months. During the study, usually transfemoral route was used for coronary angiography, percutaneous coronary intervention, percutaneous transluminal mitral commissurotomy and pulmonary valve balloon dilatation. Transradial access was performed only when modified Allen's test is normal (positive), suggesting the presence of adequate collateral circulation from the ulnar artery. The average cases for the transradial route were between 6 and 10 per month and transradial approach was used only for coronary angiography and percutaneous coronary intervention. The permanent pacemaker implantation procedures were usually done through subclavian route. It was found that the whole body radiation dose in mSv/person depends mainly on the fluoro time, which further depends on the complexity of the cath lab procedure. Figure 1 depicts the relation between the average fluoro time and the procedure type. It was observed that the average fluoro time for PTMC was maximum of 40 minutes, for PVBD; 33 minutes, for CAG+PCI; 33 minutes, for PCI; 30 minutes, for PPM 18; minutes and for CAG, it was about 8 minutes. The whole body dose profile of cardiac cath lab professionals for different procedures is shown in figure 1 and 2. It was reported that the interventionalist I.e. primary operator received the whole body dose; maximum of 0.25 mSv and minimum of 0.08 mSv in PTMC, in CAG + PCI, maximum of 0.2 mSv & minimum of 0.08 mSv, in PCI, maximum of 0.18 mSv & minimum of 0.07 mSv, in PVBD, maximum of 0.1 mSv & minimum of 0.03 mSv, in PPM, maximum of 0.08 mSv & minimum of 0.03 mSv and in CAG, maximum of 0.05 mSv & minimum of <0.01 mSv. The secondary operator received the following whole body radiation dose; in PTMC maximum of 0.18 mSv and minimum of 0.06 mSv, in CAG + PCI, maximum of 0.1 mSv & minimum of 0.03 mSv, in PCI, maximum of 0.11 mSv & minimum of 0.025 mSv, in PVBD, maximum of 0.08 mSv & minimum of 0.02 mSv, in PPM, maximum of 0.05 mSv & minimum of 0.01 mSv and in CAG, maximum of 0.03 mSv & minimum of <0.005 mSv. The whole body radiation doses for the Technologist and the Nurse were approximately same; in PTMC, maximum of 0.06 mSv & minimum of 0.03 mSv, in CAG + PCI, maximum of 0.07 mSv & minimum of 0.03 mSv, in PCI, maximum of 0.05 mSv & minimum of 0.02 mSv, in PVBD, maximum of 0.03 mSv & minimum of <0.01 mSv, in PPM, maximum of 0.02 mSv & minimum of <0.01 mSv and in CAG, maximum of 0.015 mSv & minimum of <0.005 mSv respectively.

It was observed that the primary operator (interventionalist) receives the maximum dose in all the procedures and followed by the secondary operator (assistant). Technologist and nurse being distant from the C-arm receives the lower radiation dose as compared to primary and secondary operator. Figure 3 shows a relationship between the dose received by cath lab personnels and the fluoroscopy time. It illustrates that the dose increases with the fluoro time and the primary operator receives the maximum whole body radiation dose among all the cath lab professionals. The maximum whole body radiation dose to primary operator was 0.25mSv and it was recorded in PTMC. Figure 4 gives us the relation between fluoro time and whole body radiation dose in mSv/person in radial Vs femoral route for coronary angiography and percutaneous coronary intervention. The average fluorotime for diagnostic coronary angiography through radial route was 22 minutes and through femoral route it was 14 minutes & the average fluorotime for percutaneous coronary intervention through radial route was 50 minutes and through femoral approach it was 45 minutes. It was observed that fluoroscopy time was higher for transradial route than transfemoral route. Our results suggest that there is increased operator whole body radiation exposure with the radial technique compared to the femoral technique.

DISCUSSION

Radiological examinations have an indispensable role in the diagnosis and treatment of disease, although radiation has been proven to have adverse biological effects on living organisms. These adverse effects vary according to the dose of radiation and duration of exposure.[29-32] Annually, 100-150 people die as a result of cancer secondary to medical radiation exposure. Relatively high values of radiation exposure have been considered a necessary consequence of cardiac cath lab procedures. With increasing complexity of the procedures, there has been growing concern regarding the magnitude of the exposure to operators and patients. It should be the goal of all users of fluoroscopic equipment to adhere to the ALARA principle: use of a dose level “As Low As Reasonably Achievable” for obtaining satisfactory imaging.[33-37]

In prior studies, a complete assessment has been hampered by the fact that little direct data available on the magnitude of the range of exposures in currently accepted cardiac cath lab procedures. The main source of scatter radiation received by cardiac cath lab staff is the patient. Several factors can modify the radiation risk to the staff, but if patient doses are high, the level of scatter doses will also be high. The staff radiation dose measurement and evaluation in this study illustrate that, the highest dose values were obtained from the main operator for all the procedures.

In this study we directly measured the whole body dose of the cardiac cath lab professionals using direct reading devices; pocket dosimeters of ionization type (weared over the lead apron at the neck level). The dose was recorded in relation to different cath lab procedures and fluoroscopic times. In terms of quantity, the maximum radiation dose utilized was in PTMC and the minimum dose was in CAG. In all the cases it was found that the highest dose received by the professionals is approximately equal to an abdomen-pelvis X-ray, which is well within the dose limits prescribed by the ICRP (International Commission on Radiological Protection) and the AERB (Atomic Energy Regulatory Board). In this study, The average radiation doses received by the cath lab occupational workers in different cardiac cath lab procedures agrees with that reported in previous studies, by Kim Kwang Pyo et al.[38] The cath lab staff doses were comparable with the previous literature.

Interventional procedures via transradial technique have progressively increased due to improved patient comfort, lower complication rates and reduced mortality in some scenarios. Increased radiation exposure time using the radial route is related to increase in fluoroscopy time, which reflects technical difficulties and the slightly closer operator position relative to the X-ray source and patient during the radial procedures when compared with the femoral route. In Our study the radial route was occasionally used to perform coronary angiography and percutaneous coronary interventions in order to reduce vascular peripheral arterial complications, to improve patient comfort and lower costs. It was reported that operator radiation exposure was higher during coronary angiography and PCI by the radial approach when compared with the femoral approach and, "Lang" has recently reported the same.

SUMMARY AND CONCLUSION

The potential adverse effects of radiation exposure may not be well appreciated by physicians because they are not immediate. Even cutaneous manifestations may take weeks to appear. Radiation itself is neither felt nor seen and the dosage delivered is dependent on a number of factors of which fluoroscopy time is the only one. Proper instructions in the principles of radiation physics and safety should be part of every cardiologist's education. Unfortunately, this aspect of fellowship training often receives a low priority even among physicians intending to base their careers in the catheterization laboratory. Furthermore, knowledge gained in this area is not assessed by the specialty board certification examination. Most physicians are dramatically unaware of the radiation dose, long –term risks and population health impact caused by the use of medical ionizing radiation. Thus physicians should be aware of the negative health effects of ionizing radiation. In selecting a treatment plan the benefits and risks to the individual should be considered. Thus, reducing of the exposure dose to the patient naturally reduces the dose absorbed by the operator during the procedure. It was reported that during LAO-views (rotating the X- ray tube towards the investigator), radiation exposure to the investigator is much higher (10 times or more) than during RAO-views. So, LAO-views should be replaced as much as possible by RAO-views. This study demonstrates that radiation dose varies significantly among different cathlab professionals and also depends on the procedure type and technique.

From this study, it can be concluded that radiation dose is directly proportional to fluorotime and the primary operator, who is solely handling the procedure receives the maximum whole body radiation dose in all the cath lab procedures. In our study, we found an increased radiation exposure using radial technique compared to femoral technique. A protective device could help to decrease this. There are some limitations to the study. This is a single centre stimulated study, conducted for six months and requires external validation before further conclusions may be drawn. Hence it can be concluded that the practice of cardiac catheterization needs intensive radiation protection management.

BIBLIOGRAPHY

1. Higgins CB: Cardiac imaging. Radiology, 2000; 217: 4-10.
2. International Commission on Radiological Protection (ICRP): Radiation and your patient: a guide for medical practitioners. A web module produced by Committee 3of the ICRP 2001. Oxford, UK: Pergamon press.
3. European Commission. Radiation protection 118: Referral guidelines for imaging. [http://euro.eu.int/comm./environment/radprot/118/rp-118-en.pdf]. (accessed 23 july2004).
4. Council Directive 97/43/Euratom of 30 june 1997 on health protection of individuals against the dangers of ionizing radiation in relation to medical exposure and repealing Directive 84/446/Euratom. Official journal of the European Communities L I 80: 0022-0027. 09/07/1997.
5. Picano E: Sustainability of medical imaging. Education and Debate. BMJ, 2004; 328: 578-580.
6. Shiralkar S, Rennie A, Snow M, Galland R, Lewis MH, Gower-Thomas K: Doctors knowledge of radiation exposure: questionnaire study. BMJ, 2003; 327: 371-372.
7. Finestone A, Schlesinger T, Amir H, Richter E, Milgrom C: Do physicians correctly estimate radiation risks from medical imaging? Arch Environ Health, 2003; 58: 59-61.
8. Lee Cl, Haims AH, Monico EP, Brink JA, Forman HP: Diagnostic CT scans: assessment of patient, physician and radiologist awareness of radiation dose and possible risks. Radiology, 2004; 231: 393-398.
9. Correia MJ, Hellies A, Andreassi MG, Ghelarducci B, Picano E: Lack of Radiological Awareness in a Tertiarry Care Cardiological Centre. Int J Cardiol 2005 in press.
10. Bedelti G, Botlo N, Andreassi MG, et al. Cumulative patient effective dose in cardiology. Br J Radiol, 2008; 82: 195-201.
11. Togni M, Balmer F, Pfiffner D, et al. Percutaneous coronary intervention in Europe 1992-2001. Eur Heart J, 2004; 25: 1208-13.
12. Neofotistou V, Vano E, Padovani R, et al. Preliminary refrence levels in interventional cardiology. Eur radiol, 2003; 13: 2259-63.
13. Bonomo L Del Favero C, Pesce B, et al. Agenzia per i Servizi Sanitari Regionali. La diagnostic per immagini. Lineeguida. Available at: http//www.sirm.org/prifessione/pdf_lineeguida/line_diag_x_img.pdf. Last accessed October 10, 2008.

14. Kocinag D, Cioppa A, Ambrosini G, et al. Radiation dose exposure during cardiac and peripheral arteries catheterization. Int J Cardiol, 2006; 113: 283-4.
15. Bernadi G, Padovani R, Morocutti G, et al. Clinical and technical determinants of the complexity of percutaneous transluminal corcnary angioplasty procedures: analysis in relation to radiation exposure parameters. Catheter Cardiovasc Iterv, 2005; 51: 1-9.
16. Perisinakis K, Theocharopoulos N, Damilakis J, et al. Fluoroscopically guided implantation of modern cardiac resynchronization devices. J Am Coll Cardiol, 2005; 46: 2335-9.
17. Limacher MC, Douglas PS, Germano G, et al. ACC expert consensus document. Radiation safety in the practice of cardiology. American College of Cardiology. J Am Coll Cardiol, 1998; 31: 892-913.
18. Vano E, Gonzalez L, Guibelalde E, et al. Radiation exposure to medical staff in interventional and cardiac radiology. Br J Radiol, 1998; 71: 954-60.
19. American Board of Internal Medicine. Interventional Board Requirements. Available at: http://abim.org/resources/eiblue.shtm.
20. Hirshfeld JW, Balter S, Brinker JA. ACCF/AHA/HRS/SCAI clinical competence statement on optimizing patient safety and image quality in fluoroscopically guided invasive cardiovascular procedures. J Am Coll Cardiol, 2004; 44: 2259-82.
21. European-Union. Guidelines for Education and Training in Radiation Protection for Medical Exposures. Brussels: 2000. Available at: http://europa.eu.int/comm./environment/radprot/116/rp-116en.pdf.
22. Shope TB. Radiation-induced skin injuries from fluoroscopy. Radiographics, 1996; 16: 1195-9.
23. Park TH, Eichling JO, Schechtman KB, Bromberg BI, Smith JM, Lindsay BD. Risk of radiation induced skin injuries from arrhythmia ablation procedures. Pacing Clin Electrophysiol, 1996; 19: 1363-9.
24. Dehen L, Vilmer C, Humiliere C, Corcos T, Pentousis D, Ollivaud L, et al. Chronic radiodermatitis following cardiac catheterization: a report of two cases and a brief review of the literature. Heart, 1999; 81: 308-12.
25. Authors on behalf of ICRP, Stewart FA, Akleyev AV, Hauer-Jensen M, Hendry JH, Kleiman NJ, Macvittie TJ, Aleman BM, Edgar AB, Mabuchi K, Muirhead CR, Shore RE, Wallace WH. ICRP statement on tissue reactions and early and late effects of radiation in normal tissues and organs-threshold doses for tissue reactions in a radiation protection context. Ann ICRP, 2012; 41: 1-322. Doi:10.1016/j.icrp.2012.02.001.

26. Rehani MM, Srimahachota S. Skin injuries in interventional procedures. Radiat Prot Dosimetry, 2011; 147: 8-12.
27. 27. Rehani MM, Vano E, Ciraj-Bielac O, Kleiman NJ. Radiation and cataract. Radiat Prot Dosimetry, 2011; 147: 300-304.
28. UNSCEAR 2008 Report: Sources and effects of ionizing radiation. Vol.l. http://www.unscear.org/docs/reports/2008/09-86753_Report_2008_annex_A.pdf (9 september 2013).
29. Brenner DJ, Doll R, Goodhead DT, et al. Cancer risks attributable to low doses of ionizing radiation: assessing what we really know. Proc Natl Acad Sci USA, 2003; 100: 13761-13766.
30. Lee Cl, Haims AH, Monico EP, Brink JA, Forman HP. Diagnostic CT scans: assessment of patient, physician and radiologist awareness of radiation dose and possible risks. Radiology 2004; 231: 393-398.
31. Tack D, Gevenois PA. Radiation dose in computed tomography of the chest. JBRBTR, 2004; 87: 281-288.
32. Hauptmann M, Mohan AK, Doody MM, Linet MS, Mabuchi K. Mortality from diseases of the circulatory system in radiologic technologists in the United States. Am J Epidemiol, 2003; 157: 239-248.
33. Johnson LW, Moore RJ, Balter S. Review of radiation safety in the cardiac catheterization laboratory. Cathet Cardiovsac Diagn, 1992; 25: 186-94.
34. Pattee PL, Johns PC, Chambers RJ. Radiation risk to patients from percutaneous transluminal coronary angioplasty. J Am Coll Cardiol, 1993; 22: 1044-51.
35. Zorzetto M, Bernardi G, Morocutti G, Fontanelli A. Radiation exposure to patients and operators during diagnostic catheterization and coronary angioplasty. Cathet Cardiovsac Diagn, 1997; 40: 348-51.
36. Bakalyar DM, Castellani MD, Safian RD. Radiation exposure to patients undergoing diagnostic and interventional cardiac catheterization procedures. Cathet Cardiovsac Diagn, 1997; 42: 121-5.
37. Watson RM. Radiation exposure: clueless in the cath lab, or Sayonara ALARA. Cathet Cardiovsac Diagn, 1997; 42: 126-7.
38. Kim, Kwang Pyo, Miller, Donald L, Balter, Stephen, Kleinerman, Ruth A, Linet, Martha S, Kwon, Deukwoo, Simon, Steven L. Occupational Radiation Doses to Operators Performing Cardiac Catheterization Procedures: 2008; 94: 211-227.