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Journal of Radiology & Radiation therapy

Review Article

Staff Organ Dose Assessment and Cancer Risk Estimation in a Cath-Lab Room

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Submitted: 23 January 2023
Accepted: 24 February 2023
Published: 26 February 2023
ISSN: 2333-7095

Keywords
- Skin dose
- Staff dose
- Fluoroscopy guided procedures
- Thermoluminescent dosimeters

Abstract

Staff organ doses were assessed and cancer risk were estimated for varying x-ray tube angulation in a cath-lab room at the emergency department of a hospital. Themoluminescence dosimeters (TLD) were used for the staff's eye lens, thyroid, chest and gonad dosimetry. A fabricated wood and Perspex phantom were used to represent the staff and the patient respectively. The chest (cardiologist – 0.08 mSv), thyroid (nurse – 0.13 mSv), thyroid (cardiologist – 3.26 mSv) received the highest doses comparatively at AP 0°, LAO 45° and RAO 45° x-ray tube angulation respectively. Generally, the radiation dose to the staff was high for x-ray tube angulation of right anterior oblique (RAO) 45°. The thyroid organ recorded the highest cancer incidence risk comparatively for anterior posterior (AP) 0°, left anterior oblique (LAO) 45° and RAO 45° x-ray tube angulation, and for both sexes. However, generally, the cancer incidence risk estimates for females were higher than that of the males by a maximum factor of 3.2. The highest cancer risk incidence was 342.30 per 10^5 and 172.78 per 10^5 for female and male population respectively exposed in the thyroid organ. It is therefore recommended that staff doses should be optimised by using protective equipment (i.e. lead thyroid shield) to enhance staff protection.

ABBREVIATIONS

PMMA: polymethylmethacrylate; TLD: Themoluminescence dosimeters; Hp: dose equivalent; RAO: Right Anterior Oblique; LAO: Left Anterior Oblique; AP: Anterior Posterior; BEIR: Biological Effect of Ionising Radiation.

INTRODUCTION

The use of fluoroscopy for the purpose of diagnostic and treatment have witnessed substantial improvement in medical image technology. New digital detectors coupled with sophisticated, dedicated software and large advances in computing technique that is used to obtain valuable clinical information within medical images have facilitated the expansion of fluoroscopy guided procedures [1].

Fluoroscopy diagnostic procedures are becoming a routine in many centers around the world. This is because it results in successful clinical outcome and better patient safety. Fluoroscopically-guided procedures lead to a significant number of prolonged procedures, which results in increased radiation exposure to patients and operators [2-4].

Among other categories of professional exposure, occupational exposure in fluoroscopy is one of the areas in which increased exposure is likely to occur, in particular for certain organs as extremities and eye lens [5,6]. In most situations radiation exposed workers in fluoroscopy are monitored using a single dosimeter for whole body dose assessment or using two dosemeters positioned under and above the lead apron (double dosimetry) according to international professional organizations recommendations [7]. Studies [8,9], have highlighted some drawbacks in monitoring occupational exposure in fluoroscopy such as lack of comprehensive personal dose records, in appropriate use of dosimeters etc.

This study aimed at assessing staff doses (cardiologist and nurse) at different angulation of the x-ray tube for cancer risk estimation during fluoroscopy guided procedures in the cath-lab using a wooden fabricated staff.

MATERIALS AND METHODS

This study was conducted in a newly commissioned Cath-Lab room at the emergency department of a hospital. The Cath-Lab room is equipped with an under-couch Philips Azurion 7 M20 Medical Systems (Serial Number: 173965; Total filtration: 2.5 mm of Al; Maximum tube voltage: 125 kV) fluoroscopy tube. All the necessary approvals (i.e. facility and municipal approvals) were obtained in order to conduct this study.

An acrylic polymethylmethacrylate (PMMA) phantom with dimensions 25 (length) x 25 (breath) x 20 (height) cm was used to represent the patient in order to provide the needed scatter radiation to the staff. A fabricated wood of 170 cm height with arms was used to represent the staff. Calibrated four (4) Themoluminescence dosimeters (TLD)'s were placed on the fabricated wood at different heights: 165 cm, 155 cm, 135 cm and 80 cm to measure the dose at the height of the eyes, thyroid, chest and gonad respectively as shown in Figure 1. The TLDs were calibrated in terms of shallow dose equivalent (Hp) (0.07) and deep dose Hp (10) prior to their use. The TLDs tolerance range of deviation of the element correction factors were ± 30 %. The eye lens and thyroid TLDs were unshielded but the chest and the gonad TLDs were placed under a lead apron of 0.5 mm thickness of lead as practically positioned. The organ doses were estimated from the evaluation of doses measured using the TLDs. However, the eye lens dose was measured in terms of H_p (3). Therefore, H_p (3) was estimated from the H_p (0.07) eye dosimeter reading using equation 1.

$$H_P(3) = H_P(0.07) \times e^{[-(\frac{\mu}{\rho}) \times \rho \times x]} \quad (1)$$

Where: μ/ρ represents the mass attenuation coefficient of the eye lens, *ρ* represent the density of the organ and *x* represents the depth (distance) considered.

Water has mostly been used as the best representative of the human body. Therefore, equation 2 was used to correct the measured personnel equivalent doses on wood (representative staff) to water [10,11].

$$Equivalentdoseinwater = \left[\frac{(\frac{\mu}{\rho})_{wood}}{(\frac{\mu}{\rho})_{water}}\right] \times Equivalentdoseinwood \quad (2)$$

Where $(\mu/\rho)_{wood}$ and $(\mu/\rho)_{water}$ are mass attenuation coefficient for wood and water respectively.

Figure 1 Set up measurement in the Cath-Lab showing staff position for measurements behind the lead shield and lead curtain.

The staff dose was measured at three (3) different angulations of the x-ray tube: Right Anterior Oblique (RAO) 45°, Left Anterior Oblique (LAO) 45° and Anterior Posterior (AP) 0°. The staff standing positions considered were: (1) on the left side of the patient couch behind the lead glass and the lead curtain where the cardiologists are likely to stay during procedure, and (2) on the right of the patient couch at one (1) meter from the patient without any additional shield where the nurses are likely to stay. The phantom was screened for five (5) minutes and five (5) radiographic shots for each of the identified angulation of the x-ray tube.

Organ specific cancer risk incidence was estimated from the measured organ doses using the excess relative risk model of Biological Effect of Ionising Radiation (BEIR) committee VII phase 2 report [12]. The cancer risk incidence for all solid cancers except thyroid was estimated using equation 3. The cancer risk incidence for the thyroid was also estimated using equation 4 and 5.

$$ERR = \beta_S D \exp(\gamma e^*)(\frac{a}{60})^{\eta} \quad (3)$$

Where *ERR* is excess relative risk; β_s is ERR per unit of dose expressed in Sieverts, which is dependent on sex (s); *D* is absorbed dose; γ is per-decade increase in age at exposure over the range 0 – 30 years; *e* is age at exposure (30 years); *a* is attained age at exposure (60 years); and η is exponent of attained age.

$$\frac{ERR}{Gy} = 0.53\exp[-0.083(e-30)]formales \quad (4)$$

$$\frac{ERR}{Gy} = 1.05\exp[-0.083(e-30)]forfemales \quad (5)$$

Where *ERR* is excess relative risk; *Gy* is dose in gray; and *e* is age at exposure (30 years).

RESULTS AND DISCUSSION

The radiation dose to the identified organs of the cardiologist and the nurse for different orientation of the x-ray tube has been presented in Table 1. It can be seen that for x-ray tube angulation of AP 0° radiation dose to the chest of the cardiologist was higher than that to the eye lens, thyroid and gonad by a factor of 2.0, 1.1 and 1.3 respectively. It can also be seen that for x-ray tube angulation of LAO 45°, the dose to the eye lens of the cardiologist was more than that to the thyroid, chest and gonads by a factor of 1.6, 1.8 and 1.8 respectively. However, the nurse received the highest dose to the thyroid and it was more than the dose to the eye lens, chest and gonads by a factor of 1.1, 2.6 and 1.6 respectively. The x-ray tube angulation at RAO 45° recorded the highest dose of 3.26 mSv to the thyroid of the cardiologist. The dose to the thyroid was more than that to the eye lens, chest and gonads of the cardiologist by a factor of 54.0, 4.7 and 4.7 respectively. For the same x-ray tube angulation of RAO 45° the nurse received a dose of 0.24 mSv to the thyroid that was more than that to the eye lens, chest and gonad by a factor of 1.1, 3.1 and 4.8 respectively.

It can be seen that the organs receiving the high doses varied with varying tube angulation for both the cardiologist and the nurse. This could be attributed to the proximity of these organs to the x-ray tube. The varying dose quantity to the cardiologist

Table 1: Cardiologist and nurse radiation dose at the level of the eye, thyroid, chest and gonad

X-ray Tube Angulation	Dose Equivalent, Hp (0.07) (mSv)							
	Eye lens		Thyroid		Chest		Gonad	
	Cardiologist	Nurse	Cardiologist	Nurse	Cardiologist	Nurse	Cardiologist	Nurse
AP 0^0	0.04	-	0.07	-	0.08	-	0.06	-
LAO 45^0	0.11	0.12	0.07	0.13	0.06	0.05	0.06	0.08
RAO 45^0	0.06	0.22	3.26	0.24	0.70	0.07	0.07	0.05

(-) means not available
Abbreviations: RAO: Right Anterior Oblique; LAO: Left Anterior Oblique; AP: Anterior Posterior

Table 2: Excess relative risk cancer incidence for the eye lens, thyroid, chest and gonad of female staff

X-ray Tube Angulation	Excess Relative Risk (per 10^5)							
	Eye lens		Thyroid		Chest		Gonad	
	Cardiologist	Nurse	Cardiologist	Nurse	Cardiologist	Nurse	Cardiologist	Nurse
AP 0^0	1.80	-	7.35	-	3.60	-	2.28	-
LAO 45^0	4.95	5.4	7.35	13.65	2.70	2.25	2.28	3.04
RAO 45^0	2.70	9.90	342.30	25.20	31.50	3.15	2.66	1.90

(-) means not available
Abbreviations: RAO: Right Anterior Oblique; LAO: Left Anterior Oblique; AP: Anterior Posterior

Table 3: Excess relative risk cancer incidence for the eye lens, thyroid, chest and gonad of male staff

X-ray Tube Angulation	Excess Relative Cancer Risk (per 10^5)							
	Eye lens		Thyroid		Chest		Gonad	
	Cardiologist	Nurse	Cardiologist	Nurse	Cardiologist	Nurse	Cardiologist	Nurse
AP 0^0	1.08	-	3.71	-	2.16	-	0.72	-
LAO 45^0	2.97	3.24	3.71	6.89	1.62	1.35	0.72	0.96
RAO 45^0	1.62	5.94	172.78	12.72	18.90	1.87	0.84	0.60

(-) means not available
Abbreviations: RAO: Right Anterior Oblique; LAO: Left Anterior Oblique; AP: Anterior Posterior

and nurse for the same x-ray tube angulation could be attributed to the x-ray tube orientation with respect to the staff positioning to the patient table and the protective equipment provided. Generally, tube angulation at RAO 45^o recorded high doses to the cardiologist and the nurse. It is recommended that the cardiologist and the nurse should effectively use the protective equipment (i.e. protective goggles, thyroid shield and aprons) at all times during the procedures.

Excess relative risk of cancer incidence of the eye lens, thyroid, chest and gonads of female and male staff in the cath lab room has been presented in Table 2 and 3 respectively. It must be indicated that the models used for the cancer incidence are highly speculative because of various random and systematic uncertainties embedded in them [13].

At x-ray tube angulation of AP 0^o, thyroid recoded the highest cancer incidence risk for both male and female staff. Also, for LAO 45^o and RAO 45^o x-ray tube angulation, the thyroid recorded the highest cancer incidence risk comparatively for both the cardiologist and the nurse, and the sexes. This suggest that irrespective the x-ray tube angulation in the cath-lab room, protection of the thyroid by using lead thyroid shield is very paramount. Generally, the cancer incidence risk estimates for females were higher than that of the males by a maximum factor of 3.2. The highest cancer risk incidence was 342.0 per 10^5 female population when exposed in the thyroid to a radiation dose of 3.26 mSv with age at exposure and attained age of 30 and 60 years respectively.

CONCLUSION

Staff doses have been assessed and cancer risk estimated for a cath lab room. It was observed that varied organs of the cardiologist and nurse received high doses comparatively for varying tube angulation. The chest (cardiologist – 0.08 mSv), thyroid (nurse – 0.13 mSv), thyroid (cardiologist – 3.26 mSv) received the highest doses at AP 0^o, LAO 45^o and RAO 45^o x-ray tube angulation respectively. Additionally, the quantity of radiation dose to the cardiologist and nurse varied for the same x-ray tube angulation. Generally, the radiation dose to the staff was high for x-ray tube angulation at RAO 45^o. The thyroid organ recorded the highest cancer incidence risk comparatively for AP 0^o, LAO 45^o and RAO 45^o x-ray tube angulation, and for both sexes. However, generally, the cancer incidence risk estimates for females were higher than that of the males by a maximum factor of 3.2. The highest cancer risk incidence was 342.30 per 10^5 and 172.78 per 10^5 for female and male population respectively exposed in the thyroid organ. It is therefore recommended that staff doses should be optimised by using protective equipment (i.e. lead thyroid shield) to enhance staff protection.

ACKNOWLEDGEMENTS

The authors would like to acknowledge the radiographer and the medical physicist of the hospital and the staff of school of nuclear and allied sciences for their support during the data collection.

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