OCCUPATIONAL DOSE ESTIMATION WITH FIELD SIZE, POSITION AND C-ARM GANTRY TILT VARIATIONS DURING INTERVENTIONAL CARDIOLOGY PROCEDURES

N.G. Pratiwi, S.A. Pawiro, K.T. Wigati, D.S. Soejoko

Medical Physics and Biophysics Division, Department of Physics, Faculty of Mathematics and Natural Sciences, University of Indonesia, Depok, 16424

E-mail: n.gitapratiwi@gmail.com

Abstract: In Interventional Cardiology, dose received by the patient is relatively higher, while the occupational would receive scattered radiation dose whose quality is relatively lower. However, the occupational received accumulative doses of all cardiovascular procedures were done over the years. Therefore, the purpose of this paper will focus to estimate the distribution of scattered dose to occupational without any protective shielding in the Cath Lab. The scattered dose rate was measured by using survey detector of Unfors Xi. The detector was placed at 6 different positions around the phantom. Each measurement position has eleven points from 25 to 175 cm above the floor with increment of 15 cm as the illustration of partial height of occupational organ. Experimentally a Rando phantom was irradiated by automatic pulsed fluoroscopy with condition varies in the range of 88-93 kV and 5.7-9.4 mA depend on gantry tilt and field size. The Philips C-arm gantry tilt was varied at 0^o PA projection, 20^o and 30^o Caudal, 20^o and 30^o Cranial, and 40^o and 50^o Left Anterior Oblique, and also Flat Panel Detector (FPD) was varied at 20 x 20 and 25 x 25 cm^2. Generally, the greatest dose rate was known at level corresponding to the waist (100 cm) of occupational and the lowest at head areas (175 cm) of occupational which is 2.49 mGv/h and 0.02 mGy/h, respectively. The given data showed that the scattered fractions are in the range of 0.001-0.060% from its primary dose at isocenter. The scattered doses tend to increase with gantry tilt for all positions. Increasing field size of FPD will decreased the scattered fraction from its dose at isocenter, and also it affects the scattered dose rate.

Keywords: *Interventional Cardiology, Occupational Dosimetry, Radiation Protection, Scattered Dose Rate*

Received 15 January 2014
Revised 03 February 2014
Accepted 10 February 2014
Published 28 February 2014

I. INTRODUCTION

Interventional cardiology involves fluoroscopy diagnostic which requires a long time with a low radiation intensity to guide the catheter, and cine radiography which requires a short time with high radiation intensity for documentation of actions. The numbers of percutaneous interventional procedures using radiation have continually increased since the 1960s [1]. In general, both workers and patients in interventional cardiology procedure room are exposed to ionizing radiation. Personnel should be aware of 3 different types of ionizing radiation exposure: the primary x-ray beam, scattered x-rays, and leakage x-rays. The radiation dose received by the patient is relatively higher because patients are in the primary beam, while the workers would receive scattered radiation dose whose quality is relatively lower and spread in every direction. However, different from the patients, the clinical workers received a cumulative dose of all cardiovascular measures were done over the years. Scattered radiation levels in the room are in the range 0.2 - 4.5 mSv/h during the procedure [2].

Based on the ICRP recommendations No. 60 (1990), The maximum annual dose allowed for radiation workers is 20 mSv averaged over 5 years, with no more than 50 mSv in a year. For the lens of the eye it is 150 mSv per year and 500 mSv for the skin, hands, and feet. Therefore, the occupational should be more vigilant at position that has a high scattered radiation. The discussion of the dose distribution in

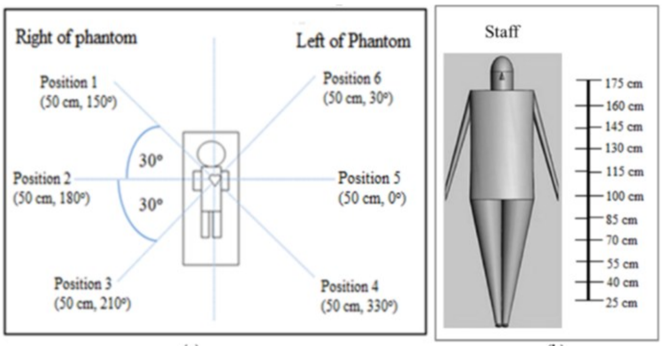

Figure 1. Simulation of (left) position and (right) Height of occupational

interventional cardiology procedures to determine the scattered radiation is very important.

II. MATERIALS AND METHODS

Rando phantom which is assumed as the body of the patient, is placed on the patient table to be irradiated with the radiation field wide 25 cm x 25 cm. Furthermore, the scattered dose rate was observed at six different positions around the patient, as in Figure 1 (left), using Unfors-Xi survey detector. Occupational position is set at a distance of 50 cm away from isocenter. Each measurement position has eleven points from 25 to 175 cm above the floor with increment of 15 cm as the illustration of partial height of occupational. The gantry tilt was varied at 0° PA projection, 20° and 30° caudal , 20° and 30° cranial, 40° and 50° LAO. The measurement was performed with the patient table height and SID (Source to Intensifier Distance) 102 cm and 100 cm, respectively.

Table 1. Dose rate at isocenter for different angles and FPD based on kV and mAs

FPD (cm^2)	Gantry Tilt	kV	mA	Time (s)	Dose Rate (mGy/s)
20x20	0	93	9.4	180	1.170
25x25	0	89	6.2	180	1.062
25x25	20 CAU	91	6.8	180	1.217
25x25	30 CAU	93	7.7	180	1.440
25x25	20 CRA	88	5.8	180	0.971
25x25	30 CRA	89	6.0	180	1.027
25x25	40 LAO	88	5.7	180	0.954
25x25	50 LAO	88	5.9	180	0.988

The results will be showed as a percentage where the scattered dose rate is divided by the value of the primary dose rate at isocenter and is multiplied by 100%. This result represents the number of relative scattered doses from its primary beam.

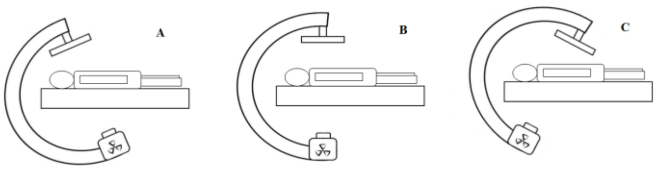

Figure 2. Simulation of gantry tilt of (a) cranial, (b) 0° PA Projection and (c) caudal

III. RESULTS AND DISCUSSION

In this study, the measurement result of air dose rate at the primary beam with a distance of 98 cm from the X-ray tube is obtained as in Table 1. To find out the air dose rate at the isocenter, which is at a distance of 50 cm from the X-ray tube, is using inverse square law formula. Thus, the value of the air dose rate at isocenter is 17.43 µGy /s.

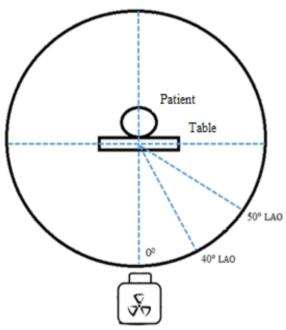

Figure 3. Simulation of gantry tilt of LAO

The Philips C-arm is used specifically for interventional, therefore being not equipped with kV and mAs settings, so the value of the dose rate at the isocenter point should be adjusted as at the time of measurement, using the following Equation 1, where $\dot{D}$ = absorbed dose rate, kV = energy in kilovoltage, mA = current in milliamps, and s = time in second. The air dose rate at isocenter at the time of measurement is showed in Table 2.

$$\dot{D}_2 = \left(\frac{kV_2}{kV_1}\right)^2 \times \left(\frac{mAs_2}{mAs_1}\right) \times \dot{D}_1 \quad (1)$$

Tabel 2. Air dose rate at a distance of 98 cm from the X-ray tube

FPD (cm^2)	kV	mA	Time (s)	µGy/s
20x20	71	4.7	6	2.959
25x25	74	4.7	6	4.537

Generally, the distribution of scattered radiation from a height of 25 cm to 175 cm follows a Gaussian distribution. This scattered results is obtained without any protective shielding in place. Scattering distribution lowest value was found in the head of the occupational (175 cm from the floor). Percentage scattering of these area of the occupational has been hindered by the patient table and the phantom. Additionally, the foot of the occupational (25 cm from the floor) also get scattered radiation with relatively small value because the area is under the x-ray tube collimator. Meanwhile, the largest value obtained in areas with height 85 cm and 100 cm from the floor. The highest value obtained for the scattering of radiation that accumulates on the patient was at table height (102 cm from the floor); at that height, additional backscatter of the patient table and the floor exists.

A. Field Size Variation

For FPD variation, the scattering fraction increased with the decrease of field size for all positions and heights. This is due to the interaction of radiation (photons) with materials that will happen less in the smaller FPD. So the smaller FPD has a scattering that is greater than larger FPD. In addition, the small size of the selected FoV will increase the value of kV on ABC (Auto Brightness Control) fluoroscopy, thereby increasing the radiation dose. This can be seen in Figure 4 through Figure 9, that the FPD 20 x 20 cm^2 has a scattering fraction that is greater than FPD 25 x 25 cm^2. In other words, the scattered dose rate received by occupational would be higher on the use of small FPD. It can also be observed that scatter faction for greater heights (130 to 175 cm from the floor) has a smaller values, especially at the height of 175 cm, where the scattering fraction for both FPD matches. It might happen because at the table height radiation has been scattered by the patient, or very little radiation penetrates through, so that this area tends to be safe.

B. Gantry Tilt Variation

When the gantry tilt of 30° and 40° CAU was applied, scattering distribution on the right and left phantom positions were not symmetrical. Position 1, 2, and 3 simultaneously has a maximum value at 100 cm height, then decrease at a height of 85 cm. While the position 4, 5, and 6 has maximum value at the height of 85 cm. Percentage distribution of scattering radiation was increased with the gantry tilt of caudal (Figures 10-15). This applies to positions 1, 2, 5 and 6. As for the position 3 and 4, the greatest percentage scattering is actually obtained for gantry tilt of 20 CAU, because positions 3 and 4 are on the caudal phantom and far from the x-ray tube.

C. Cranial Gantry Tilt Variation

For variation of cranial gantry tilt, the percentages scattering at positions 2, 3, 4, and 5 increased in line with increasing gantry tilt (as seen on Figures 16-21). However, at positions 1 and 6, on the contrary, the percentage scattering decreased with gantry tilt increase. This is because the x-ray tube is further away from the position of the 1 and 2.

D. LAO Gantry Tilt Variation

Position 4 which has a lower radiation scattering is typically safer than position 3 for the gantry tilt of 40º and 50º LAO. This is because position 3 is very close to x-ray tube, while position 4 received scattering that has been hindered by the patient table. Thus, position 3 tends to get more backscattered radiation. In the Figure 4, position 3 explains that the smaller the gantry tilt of LAO, the smaller percentage value of scattering radiation was obtained. Inversely proportional to the position 4, i.e. in Figure 5, the value of the percentage distribution of the scattering was greater for small gantry tilt. The value of which is inversely proportional to the position 3 and 4 is due to the position 4 being at a position close to the x-ray tube.

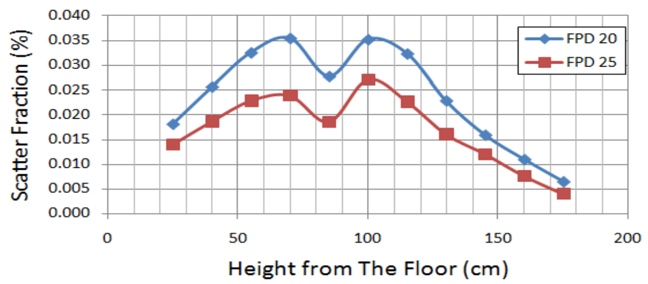

Figure 4. Graph of scattered fraction vs. the height from the floor at position 1 of field size variation

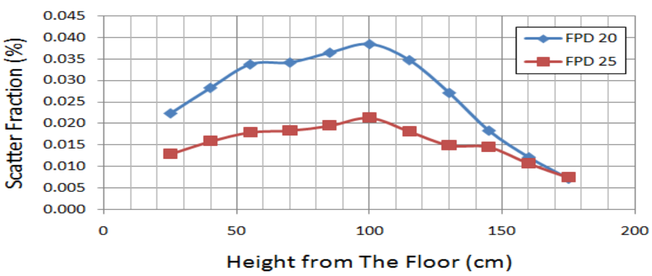

Figure 5. Graph of scattered fraction vs. the height from the floor at position 2 of field size variation

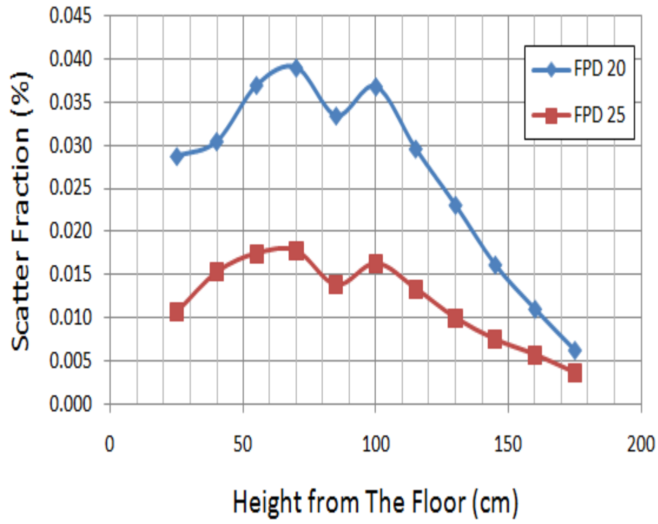

Figure 6. Graph of scattered fraction vs. the height from the floor at position 3 of field size variation

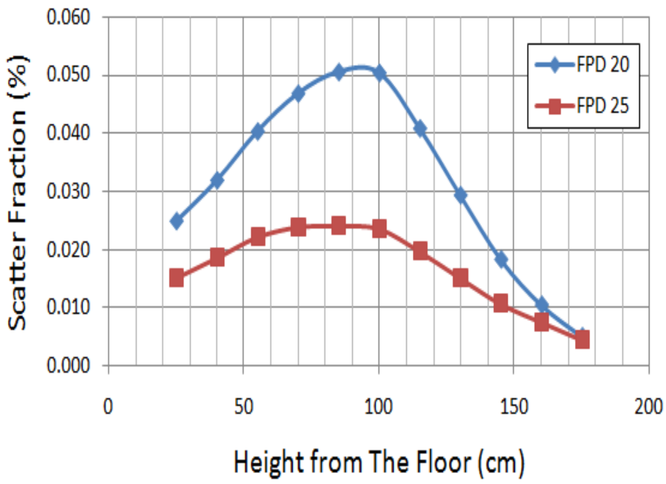

Figure 7. Graph of scattered fraction vs. the height from the floor at position 4 of field size variation

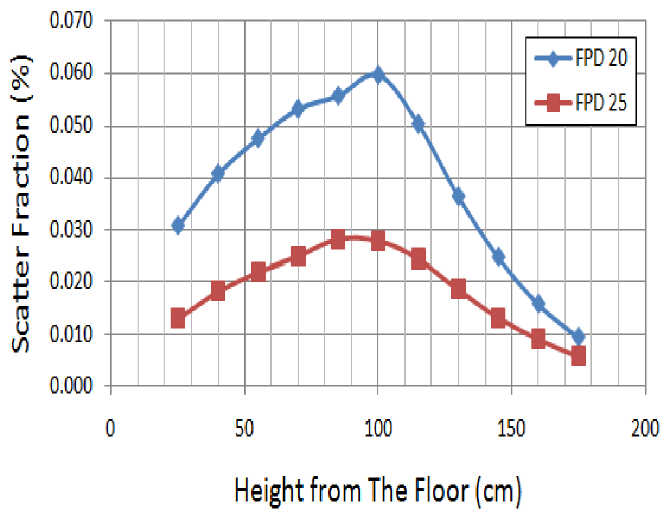

Figure 8. Graph of scattered fraction vs. the height from the floor at position 5 of field size variation

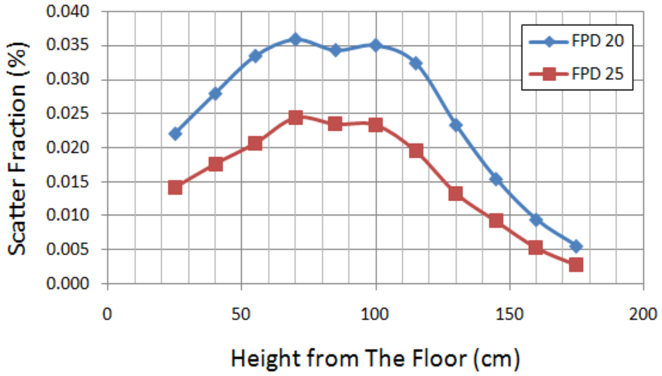

Figure 9. Graph of scattered fraction vs. the height from the floor at position 6 of field size variation

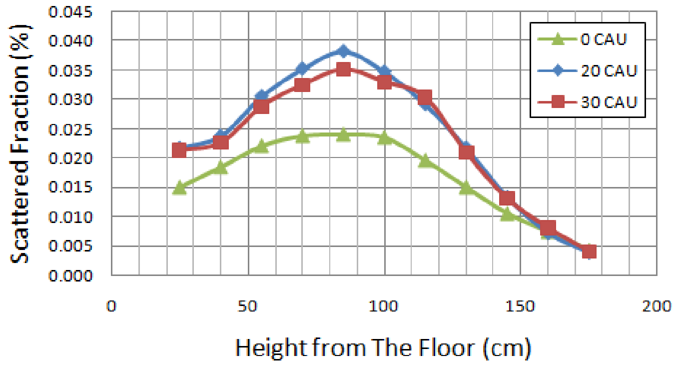

Figure 13. Graph scattered fraction vs. the height from the floor at position 4 of caudal gantry tilt variation

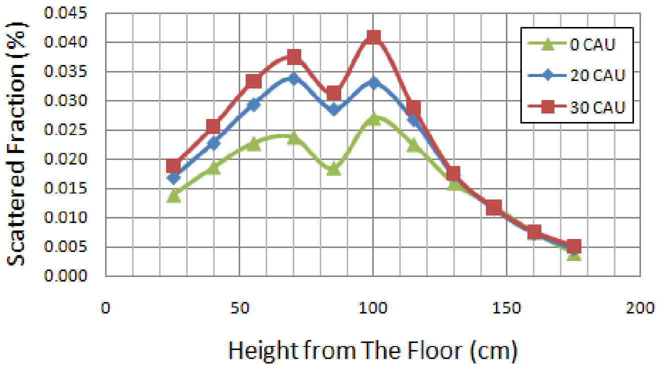

Figure 10. Graph of scattered fraction vs. the height from the floor at position 1 of caudal gantry tilt variation

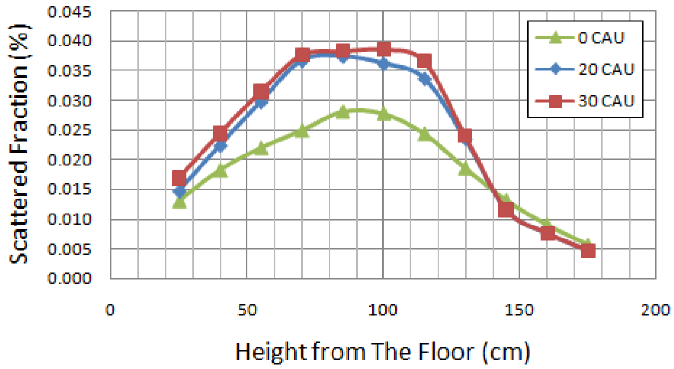

Figure 14. Graph of scattered fraction vs. the height from the floor at position 5 of caudal gantry tilt variation

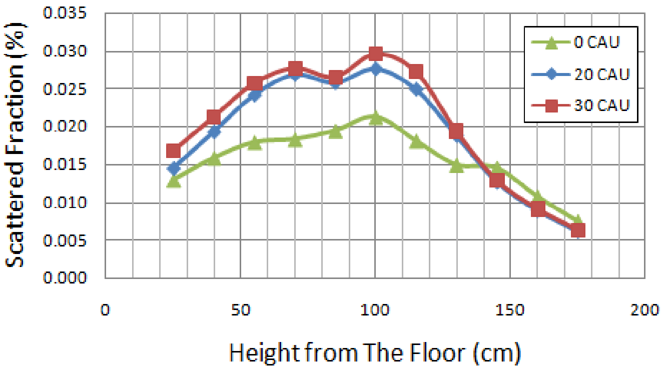

Figure 11. Graph of scattered fraction vs. the height from the floor at position 2 of caudal gantry tilt variation

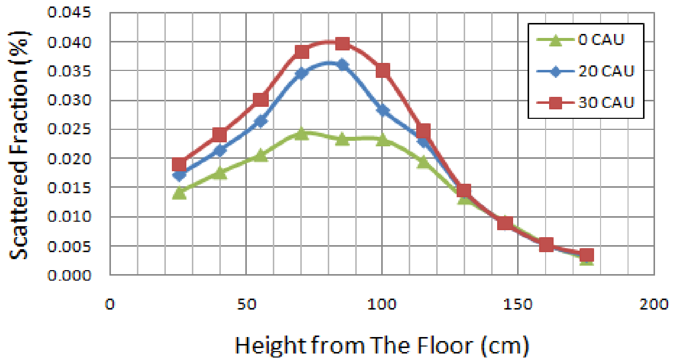

Figure 15. Graph of scattered fraction vs. the height from the floor at position 6 of caudal gantry tilt variation

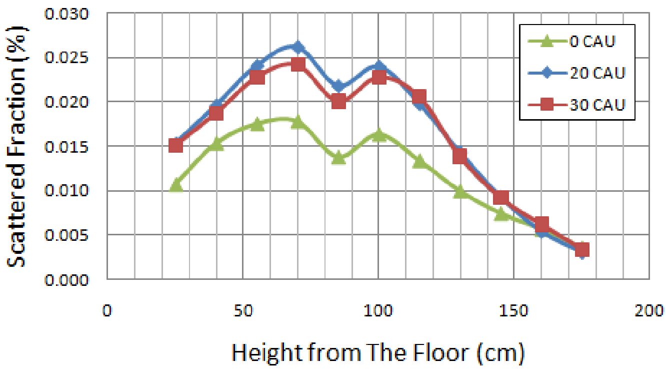

Figure 12. Graph of scattered fraction vs. the height from the floor at position 3 of caudal gantry tilt variation

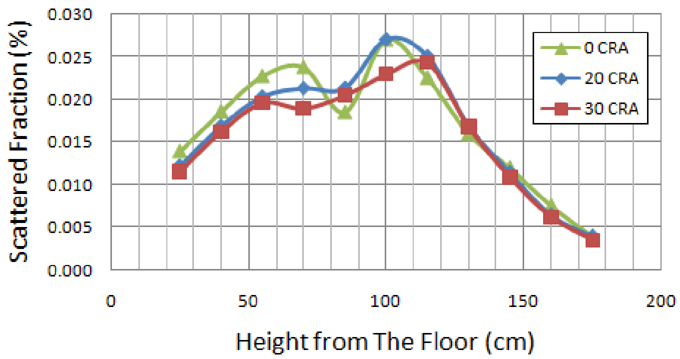

Figure 16. Graph of scattered fraction vs. the height from the floor at position 1 of cranial gantry tilt variation

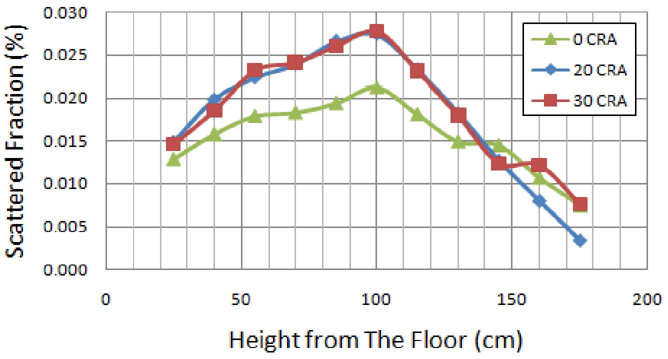

Figure 17. Graph of scattered fraction vs. the height from the floor at position 2 of cranial gantry tilt variation

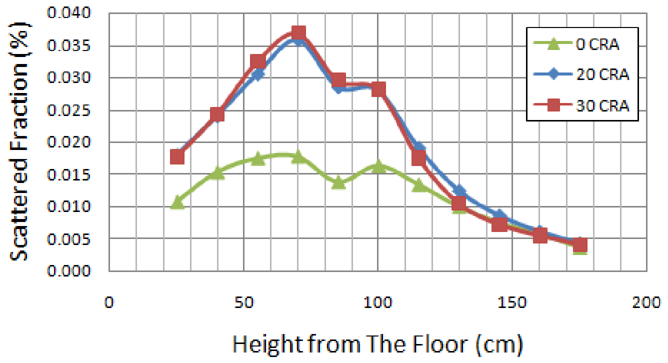

Figure 18. Graph of scattered fraction vs. the height from the floor at position 3 of cranial gantry tilt variation

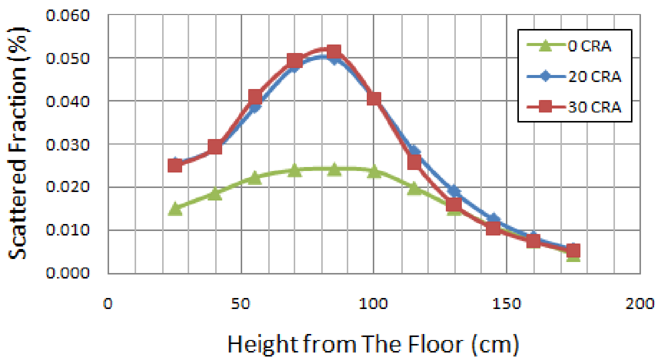

Figure 19. Graph of scattered fraction vs. the height from the floor at position 4 of cranial gantry tilt variation

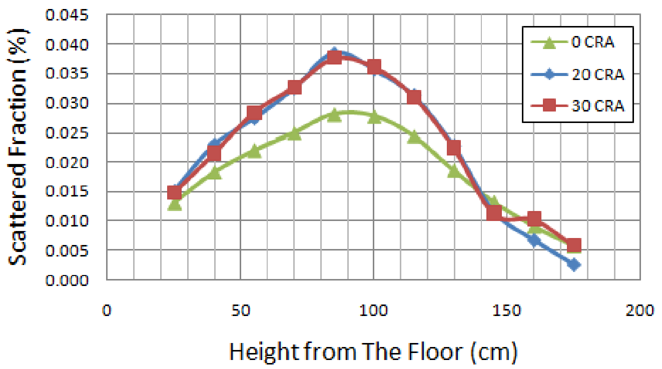

Figure 20. Graph of scattered fraction vs. the height from the floor at position 5 of cranial gantry tilt variation

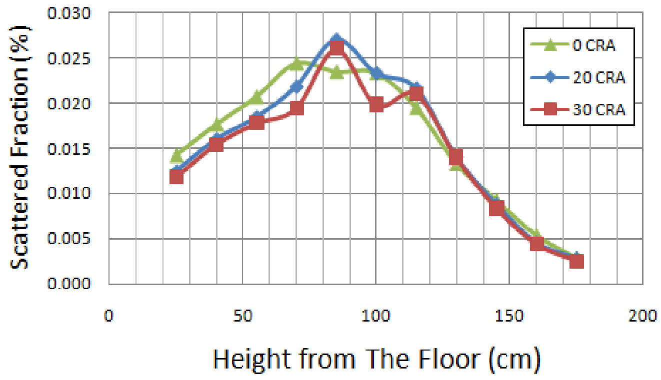

Figure 21. Graph of scattered fraction vs. the height from the floor at position 6 of cranial gantry tilt variation

IV. CONCLUSION

The scattered dose tend to increase with gantry tilt for all positions. Greater FPD size would lower the value of the scatter fraction of the dose and will minimize its scattered dose rate. The given data shown that the scattered levels are in the range of 0.001 (0.021 mGy/h) - 0.057% (1.954 mGy/h) from its primary dose at isocenter. From risk point of view, the genital organ of occupationals obtained highest scatter radiation during interventional procedures.

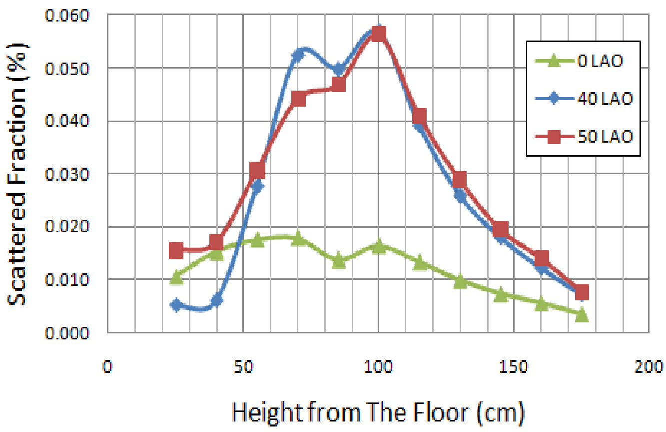

Figure 22. Graph of % relative scattering vs. the height from the floor at position 3 of LAO gantry tilt variation

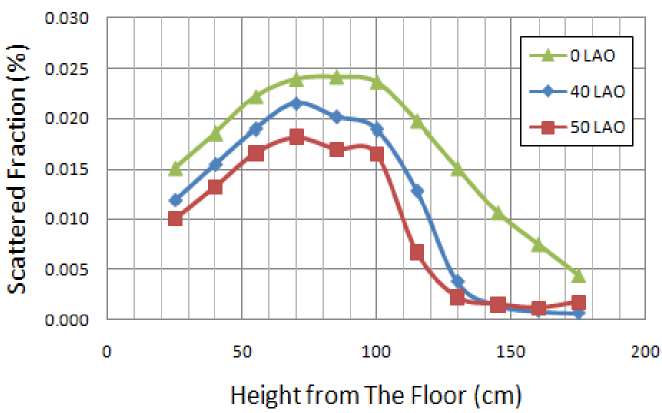

Figure 23. Graph of % relative scattering vs. the height from the floor at position 4 of LAO gantry tilt variation

REFERENCES

[1] Cousins, C., & Sharp, C. (2004). Medical Interventional Procedures-Reducing The Radiation Risks. Clinical Radiology, 468-473.

[2] AAPM report No. 70, *Cardiac catheterization equipment performance*, Medical Physics Publishing, 2001.

[3] Bushberg, J. T., Seibert, J. A., Leidholdt, E. M., & Boone, J. M. (2002). *The Essential Physics of Medical Imaging.* Philadelphia: Lippincott Williams & Wilkins.

[4] Davros, W. J. (2007). Fluoroscopy: basic science optimal use, and patient/operator protection. *Techniques in Regional Anesthesia & Pain Management* , 44-54.

[5] Domienik, J., Brodecki, M., & Rusicka, D. (2012). A Study of Dose Distribution in The Region of The Eye Lens and Extremities for Occupational Working in Interventional Cardiology. *Radiation Measurements* , 130-138.

[6] Janne, B., & Lin, P.-J. P. (2007). The Influence of Angiography Table Shields and Height on Patient and Angiographer Irradiation During Interventional Radiology Procedures. *Cardiovasc Intervent Radiol* , 448-454.

[7] Schueler, B. A. (2010). Operator Shielding: How and Why. *Techniques in Vascular and Interventional Radiology* , 167-171.