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Analysis of Radiation Exposure Dose according to Location Change during Radiation Irradiation

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Abstract

During an X-ray examination, the beam of radiation is dispersed in many directions. We believe that managing radiation dose is about providing transparency to users and patients in the accurate investigation and analysis of radiation dose. The purpose of measuring the radiation dose as a function of location is to ensure that medical personnel using the equipment or participating in the operating room are minimally harmed by the different radiation doses depending on their location. Four mobile diagnostic X-ray units were used to analyze the radiation dose depending on the spatial location. The image intensifier and the flat panel detector type that receives the image analyzed the dose by angle to measure the distribution of the exposure dose by location. The radiation equipment used was composed of four units, and measuring devices were installed according to the location. The X-ray (C-arm) was measured by varying the position from 0 to 360 degrees, and the highest dose was measured at the center position based on the abdominal position, and the highest dose was measured at the 90° position for the head position when using the image intensifier equipment. The operator or medical staff can see that the radiation dose varies depending on the position of the diagnostic radiation generator. In the image intensifier and flat panel detector type that accepts images, the dose by angle was analyzed for the distribution of exposed dose by position, and the measurement method should be changed according to the provision of dose information that is different from the dose output from the equipment according to the position.

Keywords: *Diagnostic X-ray Generating Device, Exposure Dose, C-arm, X-ray Shielding*

1. Introduction

In countries utilizing radiation, accurate radiation dose measurement is essential for the health and safety of the population [1]. When considering radiation protection for patients undergoing diagnostic and therapeutic procedures other than radiation therapy, the uncertainty in dose measurement can be even greater [2]. The traceability of measurements with defined levels of uncertainty is also crucial [3].

These advantages have increased the utilization rate of medical imaging over recent decades, resulting in a significant rise in the total radiation dose from radiographic imaging [4]. While this increased utilization is generally justified, considering the derived benefits, the resulting increased exposure necessitates a higher level of oversight for radiation protection of patients [5].

The risk of low-dose radiation in medical imaging has not been proven. It's challenging to prove the risks

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associated with low-dose radiation, partly because there are other carcinogens present in the environment, including smoking, chemicals, and pollutants. I believe that having exposure dose information based on low-dose radiation positions would be more helpful for exposure management among medical staff. I hope this study will contribute, even if only slightly, to research on the side effects of radiation due to low-dose exposure in the future.

2. Methods

2.1. Instruments

The composition of the ion chamber is designed to measure the size of the dose and the amount of rate according to time, and the characteristics of the instrument used are Radical 9010 10X5-1800 ion chamber (Table 1).

Table 1. Ion Chamber Specifications

Chamber	Radical 9010 10X5-1800 ion chamber	
Minimum Rate	0.01 mR/hr	0.1 µGy/hr
Maximum Rate	65 R/hr	575 mGy/hr
Minimum Dose	0.1 µR	0.01 nGy
Maximum Dose	230 R	2 Gy
Cine specifications	N/A	
Calibration Accuracy	±4% using X-rays @ 150 kVp & 10.2mm Al HVL	
Exposure Rate Dependance	+0%, -5%, 0.1mR/hr to 20 R/hr, -10% to 65 R/hr	
Energy Dependance	±5%, 33 keV to 1.33 MeV (with build-up material)	
Construction	Polycarbonate walls and electrode; conducting graphite exterior coating; 1800cm3 active volume; 0.54 kg	

2.2. Radiation generators for diagnostic measurement equipment (4 C-arms in total)

The measurement equipment used was a Korean FPD type C-arm, a German FPD type C-arm, a Korean image intensifier type C-arm, and a German image intensifier type C-arm for each type of FPD (Flat Panel Detector) and I.I (Image Intensifier) (Table 2).

Table 2. Measuring instruments FPD, I.I type X-ray tube specifications

Categorization list	Korean FPD type C-arm	German FPD type C-arm	Korean I.I type C-arm	German I.I type C-arm
Maximum peak voltage	130kV	125kV	130kV	125kV
Anode angle	10°	10°	10°	9°
Maximun anode dissipation	300W (2400 HU/min)	1000W (81kHU/min)	300W (2400 HU/min)	600W
Anode heat storage capacity	150kJ (200kHU)	260kJ (365kHU)	150kJ (200kHU)	60kJ
Focal Spots · mm	0.3/0.6	0.3/0.6	0.3/0.6	0.6
FPD type	CsI	CMOS	N/A	

2.3 Experimental Methods

2.3.1. Dosimetry experiment sequence by location

(1) On the patient's table, centered on side B, select a point 70 centimeters from the head as side A and 70 centimeters from the legs as side C (Figure 1).

(2) Measure the leakage dose using an 1800 cc ion chamber at the center position of the spatial 9 point coordinates center(E, Y), 0°(D, Y), 45°(D, X), 90°(E, X), 135°(F, X), 180°(F, Y), 225°(F, Z), 270°(E, Z), 315°(D, Z) by side angle. (Figure 1)

(3) The distances between the coordinates of each point are 50cm, and points at 225°(F, Z), 270°(E, Z), and 315°(D, Z) are 50cm above the ground.

(4) The measurement voltage conditions are set to 50kV, 60kV, 70kV, 80kV, 90kV, 100kV, and 110kV.

(5) The measurement current conditions are 1mA, 2mA, 3mA, and 4mA.

(6) After measuring the dose at each side angle in the space five times, calculate the A.V (average), S.D (standard deviation), and C.V (coefficient of variation) values.

(7) After analyzing the dose and verifying the validity of the values, verify the differences in radiation dose by parameter.

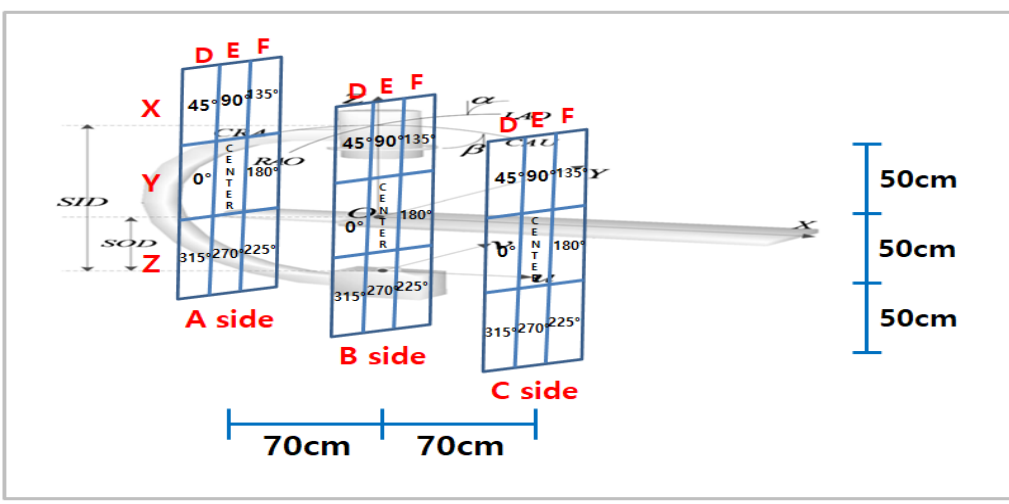

Figure 1. Illustration of the measured position by angle for each position of the C-arm

3. Results

3.1. Verification of the average radiation dose difference by equipment

To assess the reliability of the radiation dose for the diagnostic X-ray generating devices, C-arm of four different types, we first verified the average radiation dose differences. Results from verifying 756 exposure dose values for each device showed a significance probability (p) value of less than .001, confirming that there was a radiation dose difference for each equipment with values smaller than .05. To verify specific differences in average between groups, post-hoc tests were conducted. Analytically, the radiation dose of the domestic Flat panel type C-arm was significantly higher than that of the domestic image intensifier type C-arm and the foreign Flat panel type C-arm. However, there was no significant difference with the foreign image intensifier type C-arm compared to the other groups.

Table 3. Validate average differences in radiation dose across devices

Classification by equipment	Mean	Std. Deviation	F	Sig. (P)
Korean Flat panel type C-arm	39929.03	174702.866	5.534	.001
Korean image intensifier type C-arm	16886.87	75645.082		
German Flat panel type C-arm	19307.08	89619.372		
German image intensifier type C-arm	24478.61	119369.526		

3.2. Verification of the average radiation dose difference by position (angle)

Results from verifying the average radiation dose difference by position (angle) showed a significance probability (p) value of less than .001, confirming that there was a radiation dose difference for each position with values smaller than .05. To verify specific differences in average between groups, post-hoc tests were conducted. Analytically, the radiation dose at the Center was the highest, followed by 90 degrees. In contrast, 0 degrees, 45 degrees, 135 degrees, 180 degrees, 225 degrees, 270 degrees, and 315 degrees were significantly lower than the Center and 90 degrees, but there was no significant difference with other angles. Based on the data mentioned above, we conducted an analysis of exposure dose data by spatial position.

Table 4. Validate average differences in radiation dose based on location

Unit : μR/min

Location (Angle)	Mean	Std. Deviation	F	Sig. (P)
0°	654.50	953.011	66.796	.000
45°	574.45	856.215		
90°	92767.97	199263.493		
135°	530.80	606.563		
180°	616.44	822.888		
225°	336.76	469.991		
270°	226.59	565.766		
315°	290.03	430.744		
Center	130356.05	270085.614		

3.3. Exposure dose measurements by position for the entire equipment

Exposure doses by position for the entire equipment were represented using the average values of the measured doses in the following graph. The radiation dose from the C-arm equipment was highest at the Center. Next, the dose was measured higher at the 90° position. For the remaining angles, exposure doses below 0.05 were measured, indicating that there is not a significant difference in radiation dose by position.

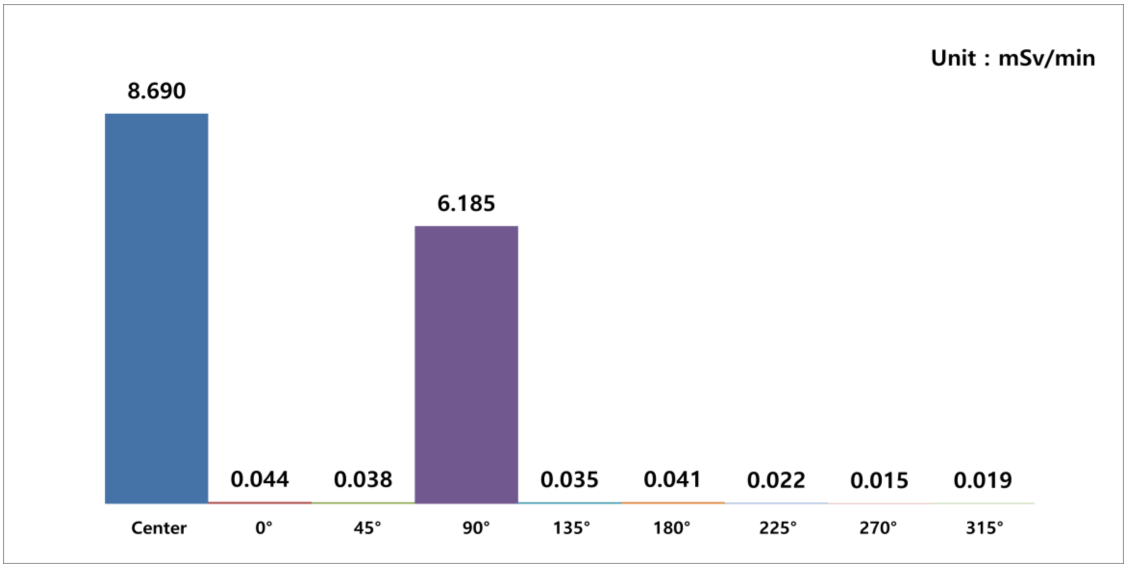

Figure 2. Average effective dose rates by location for the entire equipment

3.4. Exposure dose measurements by position for the entire equipment and by equipment type

Exposure dose measurements by position for the entire equipment and by equipment type were compared and represented graphically based on the angle for four C-arm devices from Korean and German manufacturers. At the 90° position, the exposure dose value from the German I.I type C-arm device was the highest, while at the other positions, the exposure dose value from the Korean FPD type C-arm device was the highest.

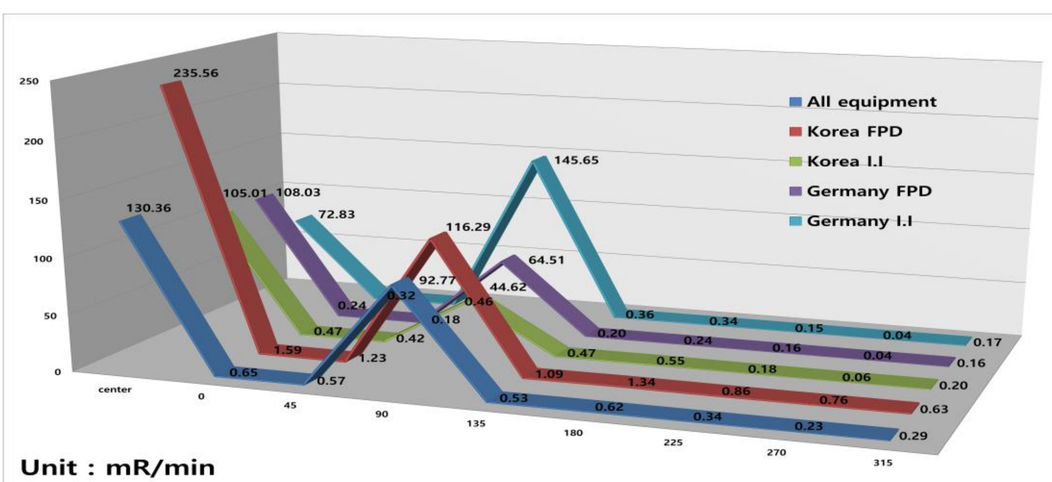

Figure 3. Graph of radiation exposure dose rates by angle for each equipment

4. Discussion

Using I.I type and FPD type C-arm devices from Korea and Germany, we conducted analyses based on measured doses by position. We utilized one-way ANOVA and two-way ANOVA to verify the average radiation dose differences by equipment and by position, and also analyzed the doses.

After verifying the exposure dose values for the four diagnostic X-ray generating C-arm devices, the significance probability (p) value was less than .001, confirming that there was a radiation dose difference for each equipment with values smaller than .05. The radiation dose of the domestic Flat panel type C-arm was significantly higher than both the domestic image intensifier type C-arm and the foreign Flat panel type C-arm. However, there was no significant difference with the foreign image intensifier type C-arm compared to the other groups.

The analysis of radiation dose average differences by position (angle) showed a significance probability (p) value of less than .001, confirming that there was a radiation dose difference for each position with values smaller than .05. The radiation dose was highest at the Center, followed by 90 degrees. On the other hand, doses at 0 degrees, 45 degrees, 135 degrees, 180 degrees, 225 degrees, 270 degrees, and 315 degrees were significantly lower than at the Center and 90 degrees, but no significant difference was observed among other angles.

The exposure dose by position for the entire equipment was represented graphically using the average values of the measured doses. The highest dose from C-arm equipment was measured at the Center, followed by the 90° position. For the other angles, doses below 0.05 were measured, indicating no significant differences in radiation dose by position.

Exposure dose measurements by position for the entire equipment and by equipment type were analyzed based on the angle for four C-arm devices from Korea and Germany. The highest exposure dose was measured at the 90° position for the German I.I type C-arm device, while for the other positions, the exposure dose from the Korean FPD type C-arm device was the highest.

5. Conclusion

During diagnostics and examinations, both patients and medical staff remain near the equipment. Even when wearing radiation shielding protective gear, the accumulated exposure dose is likely to increase. Patients and medical staff should make efforts to reduce and manage exposure doses, recognizing the risks associated with exposure. Obtaining high-quality images of patients is crucial. However, the more one aims to acquire high-quality images, the higher the exposure dose tends to be. While there's no limit to patient exposure due to its justification, if medical staff manage exposure doses based on indicators of exposure levels around patients and X-ray equipment, the burden of radiation exposure damage could be reduced. We hope that future research will focus on reducing exposure doses through studies with various parameters.

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