Journal of Engineering and Applied Sciences 13 (Special Issue 3): 3193-3197, 2018
ISSN: 1816-949X

Location of Shielding Material and Size of Radiation Field in Radiographic Procedures for Neurocranium Affect Entrance Surface Dose in Major Organs

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Abstract: The purpose of this study was to determine the effect of the location of cylinder thyroid shielding materials and the size of radiation field in radiographic procedures for neurocranium on entrance surface dose in major organs. Two SID (100 and 70 cm) of DR system with exposure conditions at 76 kVp and 25 mAs were used. ESD was measured by using OSLD and ART phantom with maximum radiation field of and 8×10 inch. Measurement points included the left, the right, the anterior and the posterior of the thyroid area using thyroid shielding. The ESD values of maximum field at the back shield were lower (SID 100 and 70 cm: 85.9 and 63.4% lower, respectively) than those at the front shield. For 8×10 inch field, the ESD values were lower by 64 and 54.3% for SID 100 and 70 cm, respectively. The ESD values when the cylinder device was used were lower by 67 and 27.6% for SID 100 and 70 cm, respectively. In addition, for SID 100 cm, the orbit ESD with maximum field was the highest (200.62 μSV). Orbit ESD value was lower by 54.4% (91.57 μSV) for a field of 8×10 inch. It was also lower by 57% (86.28 μSV) when cylinder device was used. For SID of 70 cm, orbit ESD value with the maximum field was the highest (262.18 μSV). It was lower by 28% (188.87 μSV) than that for a field of 8×10 inch. It was also lower by 64% (94.59 μSV) when the cylinder was used. Using cylinder device and back shielding for the thyroid could reduce ESD in sensitivity organs of patients.

Key words: Cylinder, shielding material, ESD, thyroid, OSLD, SID

INTRODUCTION

Since, its discovery by W.C. Roentgen in 1895, X-ray has been used for medical imaging for more than 100 years. It is the most powerful tool for the diagnosis of diseases in medical field. However, radiation doses in patients have been continuously increasing due to the use of advanced medical devices and the development of medical technology (MFDS., 2013). Medical radiation exposure is of great interests in terms of technical effort and radiation technologists to reduce radiation exposure to patients. Although, radiation has benefit for diagnosis and treatment, it will also increase the exposure of patient to radiation (Ryeon, 2011). The ALARA concept by ICRP has recommended that optimized image quality should be maintained while reducing radiation dose to ensure the legitimacy of examination during medical imaging (Jong, 2013). However, there is a lack of awareness of adjustment for X-ray field size and appreciated radiation dose compared to using Film and Screen (FS) in the past. Radiation dose might be increased when field size is larger than the diagnosis area, leading to unnecessary exposure of important organs to radiation which can damage normal organs. In total of 333 medical institutions, 204 (61.3%) are using appropriate field size for each exposure part. While 43 (12.9%) and 86 (25.8%) institutions are using Partial control and no control, respectively for the field size. A total of 129 (38.7%) of the 333 investigated institutions have used inappropriate field size. Moreover of 117 institutions with DR system, 76 (65.0%) institutions used appropriate field size while 41 (35.0%) used inappropriate field size (Kim *et al*. 2013). Unnecessary radiation exposure can also arise when X-ray is in collision with materials or when the direction is changed to another place. Moreover, scattering radiation can affect image quality. Therefore, appropriate method is needed to protect and reduce scattering radiation during X-ray examination (Choi, 2013). To reduce scattering radiation,

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one of the most general methods is by reducing field size. The field size has to be always limited by exposure area because reduced field size might increase image contrast and decrease scattering radiation, thus, reducing radiation exposure dose to patients (Carlton, 2006). In examination of microscopic lesions such as PNS, mastoid and optic foremen, although, using a cylinder device can improve image quality and decrease scattering radiation in reality the use of cylinder device and field size control are ignored due to inconvenience and discomfort for involved in the exchange or control according to exposure legions. The objective of this study was to measure Entrance Surface Dose (ESD) on the orbit and the thyroid when adjusting the size of radiation field and using a cylinder device during radiographic procedures for neurocranium. The changes of thyroid ESD values when shielding the front, the back and both shielding materials were determined. Results of this study might provide basic data to prepare measures to reduce radiation exposure by adopting effective location of a shielding material with a cylinder device.

MATERIALS AND METHODS

Research equipment: The X-ray equipment used in this study was Definium 6000 digital radiography system. OSLD nanoDot dosimeter was used to measure ART Phantom (a human body-equivalent material) and dose. Thyroid Apron (0.5 mmPb) was used as a shielding material. In addition, X-ray cylinder device commonly used in clinical trials was used in this study (Fig. 1).

Research methods: DR system was used to meet the fallowing shooting conditions suggested by the Ministry of Food and Drug Safety: tube voltage at 76 kVp, tube current at 25 mAs, Standard Distance (SID) at 100 or 70 cm. SID was defined as the distance between the cylinder and the neurocranium. To measure the maximum radiation field, radiation in a field of 8×10 inch and ESD values on the thyroid when using a cylinder device, OSLD nanoDot was attached to the right and the left of the thyroid of ART phantom. ESD was measured when shielding the front the back of the thyroid as well as when shielding both sides simultaneously (Fig. 2).

Fig. 1: X-ray equipment; a) DRS-definium; b) ART phantom; c) OSLDnanoDot and d) X-ray cylinder

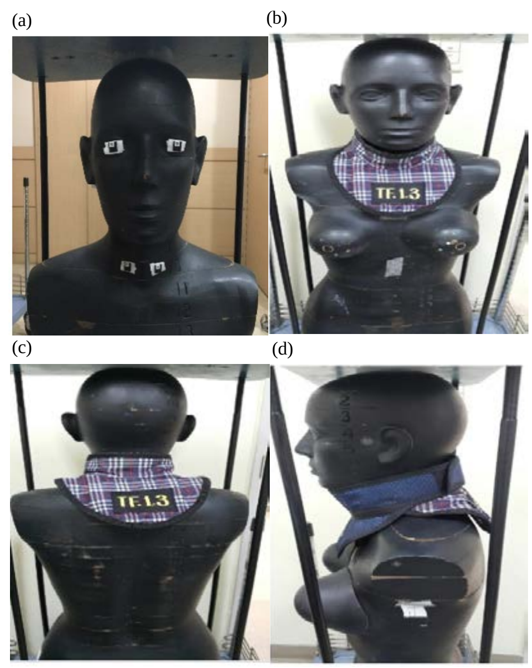

Fig. 2: NanoDot was attached while the front, back and both front and back are shielded with a shielding material

RESULTS AND DISCUSSION

ESD on the thyroid depends on the size of radiation field and the location of the shielding material in the case of SID of 100 cm: At the maximum radiation field, ESD was

Table 1: Results of thyroid ESD values

		Thyroid shielding		
SID/Types	Not	Front	Back	F and B
100 cm				
Full	423.528	292.045	41.219	43.928
8×10 inch	150.088	104.939	37.692	42.551
Cylinder	125.653	107.822	35.636	39.628
70 cm				
Full	540.860	246.404	90.164	108.401
8×10 inch	251.893	178.182	81.437	92.050
Cylinder	69.015	68.151	49.341	57.941

Table 2: Shielding effect on ESD values

Shield	z-values	p-values
Not-Front	-2.201	0.028
Not-Back	-2.201	0.028
Not-F and B	-2.201	0.028

lower by 85.9% when shielding the back of the thyroid compared to that when shielding the front of the thyroid. ESD was lower by 64% in the case of radiation field of 8×10 inch. It was lower by 67% when a cylinder device was used (Table 1).

ESD on the thyroid depends on the size of the radiation field and the location of a shielding material in the case of SID of 70 cm: At the maximum radiation field, ESD was lower by 63.4% when the back of the thyroid was shielded compared to that when the front of the thyroid was shielded. ESD was lower by 54.3% in the case of radiation field of 8×10 inch. It was lower by 27.6% when a cylinder device was used (Table 1).

In terms of the decrease in ESD value depending on the size of radiation field and the location of the shielding material, there was statistically significant ($p<0.05$) difference among the three cases (shielding the front of the thyroid, shielding the back of the thyroid and shielding both front and the back of the thyroid) (Table 2).

ESD on the orbit depends on the size of the radiation field and the location of the shielding material in the case of SID of 100 cm: ESD was the highest at 200.62 μSV with the maximum radiation field. It was lower by 54.4% in the case of radiation field of 8×10 inch (at 91.57 μSV). Compared to the ESD value at the maximum radiation field, the ESD was lower by 57% (at 86.28 μSV) when a cylinder device was used (Table 3).

ESD on the thyroid depends on the size of the radiation field and the location of the shielding material in the case of SID of 70 cm: ESD was the highest (at 262.18 μSV) with the maximum radiation field. Compared to the ESD value at the maximum radiation field. ESD was lower by 28% (at 188.87 μSV) with radiation field of 8×10 inch. Compared

Table 3: Results of orbit ESD values

SID/Collimation	Orbit
100 cm	
Full	200.62
8×10 inch	91.57
Cylinder	86.28

Table 4: Results of orbit ESD values

SID/Collimation	Orbit
70 cm	
Full	262.18
8×10 inch	188.87
Cylinder	94.590

to the ESD value at the maximum radiation field, the ESD value was lower by 64% (at 94.59 μSV) when a cylinder device was used (Table 4).

Statistical analysis was performed using SPSS (Ver. 18.0). Wilcoxon signed-ranks test revealed significant ($p<0.05$) differences among ESD values when the front, the back and both front and back were shielded according to SID and radiation field size.

X-ray has been increasing used in the radiation diagnosis filed, since, its first discovery by W.C. Roentgen. However, there is a lack of understanding for the control of radiation field size, appropriate adequate radiation dose and scattering dose when using it in medical imaging field. The DR system has been universally used due to the recent development in modern medicine. However, the lack of understanding on radiation field size could increase radiation exposure dose to patients when radiation field size is increased. Using unnecessary large field size has increased radiation dose to patients, leading to damages to sensitive normal organs in practice.

A previous study has reported that the basic method for reducing radiation dose to patients is by decreasing radiation field size and sparing patient skin to reduce scattering dose and improve image contrast (Ahn *et al*., 2010).

For facial bone, the manual method with consistent condition could decrease radiation dose for the lens and thyroid by decreasing the size of radiation field. Using the Automatic Control Radiation (ACR) mode to decrease field size can decreased radiation dose to the thyroid. However, radiation dose received by the lens is increased (Powys *et al*., 2012).

Therefore, appropriate manual method should be used to adjust the radiation condition and control the size of radiation field size to reduce the radiation exposure dose and decrease the scatter effect on the lens and thyroid.

In the study, ACR system was not applied. The sizes of radiation field used in this study were the maximum and a field of 8×10 inch. We used two SID values: 100 and

70 cm. We also determined the effect ofcylinder device use on ESD values. Our results showed that the ESD value for lens was the highest at the maximum radiation field. The ESD value was lowered by 55% when radiation field of 8×10 inch was used and by 28% when a cylinder device was used. In addition, the ESD value was lowered by 57 and 64% when SID value were 100 and 70 cm, respectively. For the thyroid, the ESD value was lower in conditions that maximum field size, 8×10 inch and used the cylinder.

Gyu (2015) have evaluated whether the use of water filter could reduce radiation exposure while improving image quality. Similar study has been performed to determine whether the use of echo-bismuth material could shield the thyroid and reduce radiation exposure (Kim, 2016). However, our study only used lead shield material and evaluated it under various conditions.

In addition, Park *et al.* (2015) have reported that using SID at 130 cm could reducing expands of the image. In our study, SID at 100 and 70 cm, the SID of standard exposure method for the neurocranium area were used.

In addition, the effect of shielding location for the thyroid with a cylinder device on radiation dose during neurocranium was evaluated. In PNS water's exposure, the ESD value by shielding the thyroid in both the anterior and posterior directions were lowered by 67 and 27.6% for SID at 100 and 70 cm, respectively compared to the ESD value when only the anterior direction of thyroid was shielded.

CONCLUSION

ESD values of orbit were measured to determine the effect of radiation field size, the used of cylinder devices, and the location of shielding position during neurocranium on radiation exposure reduction.

We used ART phantom, an equivalent human tissue, and established the optimum conditions (76 kVp, 25 mAs, 320 mA and 100 cm of SID). The ESD value was then measured at 70 cm of SID. The results for ESD measurement are as follows.

We have changed these parameters that the field size with 100 cm of SID and location of shielding materials and selected maximum field size. The ESD value when the back of the thyroid was shielded was smaller by 85.9% than that when the front of the thyroid was shielded. Moreover, the ESD values with radiation field of 8×10 inch and the use of cylinder device were smaller by 64 and 67%, respectively.

Also, we have changed these parameters that the field size with 70 cm of SID and location of shielding materials and selected maximum field size. The ESD value when the back of the thyroid was shielded was smaller by 63.4% than that when the front of the thyroid was shielded. Moreover, the ESD values with radiation field of 8×10 inch and the use of cylinder device were smaller by 54.3 and 27.6%, respectively.

We demonstrated that back shielding of the thyroid was more effective than front shielding and both front and back shielding in reducing the ESD values.

The ESD value with the maximum field size (41.0×41.0 cm) at SID of 100 cm was higher than as 200.62 μSV. At radiation field of 8×10 inch, the ESD value was smaller by 54.4% (ESD = 91.57 μSV) than that at maximum field size. With the use of cylinder device, the ESD value (86.28 μSV) was smaller than that at the maximum field size by 57%. Moreover, with SID of 70 cm, the ESD at maximum field size was 262.18 μSV which was higher by 28% than that (188.87 μSV) at radiation field size of 8×10inch field size. With the use of cylinder device, the ESD value (94.59 μSV) was smaller by 64% than that at the maximum field size of radiation.

In summary, the use the cylinder device in DR system greatly decreased the ESD values of orbit and thyroid. Therefore, to reduce radiation exposure dose in patients, back shielding of thyroid and the use of cylinder device are recommended when performing medical imaging for sensitive regions.

LIMITATIONS

This study had some limitations. First we did not apply 37° for the PNS water's method because ART phantom and OSLD nanoDot measurement could only use one element.

RECOMMENDATIONS

Future study will be needed to evaluate the effect of reducing exposure angle while using ART phantom and various shielding materials on radiation dose. In addition, comparison between OSLD and TLD measurement tools is needed to determine their effect in reducing radiation exposure.

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