〈Regular Article〉

Patient-protective Radiation Protection Shields Used During Computed Tomography (CT) Examinations Reduce the Scattered Dose in CT Room

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ABSTRACT **Objective**: This study aimed to conduct a comparative analysis of the computed tomography (CT) scatter radiation dose healthcare workers are exposed to with and without the radiation protection shields (RPS).

Methods: A helical scan of a routine triple-phase liver CT protocol was performed using a tissue-equivalent phantom via a 64-detector-row CT scanner. Scattered doses were measured and compared with and without RPS wrapped around the neck to chest outside the imaging area using a calibrated pocket electron dosimeter. We measured at 50 cm, 100 cm and 150 cm above the floor at a total of 57 points in front, to the side and behind the gantry, at 50 cm intervals from the centre of the gantry. The heights of 50 cm, 100 cm and 150 cm from the floor assume the estimated positions of the gonads, mammary glands and lens, respectively.

Results: Using RPS outside the imaging area reduced the scattered dose by about 10% at all measurement positions and heights ($p < 0.05$).

Conclusion: The use of RPS on patients during CT examinations reduces the scattered dose in the CT room by approximately 10%. doi：10.11482/KMJ-E202450025 *(Accepted on May 14, 2024)*

Key words：Radiation protection shields, Triple-phase liver CT, Healthcare workers, Scattered dose

INTRODUCTION

Advancements in computed tomography (CT) equipment have facilitated the efficient execution of comprehensive examinations within shorter time frames[1-2]. Specifically, CT angiography has demonstrated its usefulness in delineating the systemic arteries[3-5]. The contrast enhancement techniques have also undergone significant progress; these encompass the optimisation of contrast enhancement through innovations, such as tube devices[6-7]; contrast enhancement methods employing the body size index[8-9]; and the use of

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Fig. 1. Whole-body human-equivalent phantom (Whole Body Phantom PBU-10; Kyoto Kagaku, Kyoto, Japan) without (A) and with (B) the RPS.

contrast enhancement optimisers[10−11]. However, there have been minimal advancements in exposure reduction techniques for healthcare professionals operating in CT rooms such as the pediatric emergency CT examination.

In recent years, many manufacturers have marketed radiation protection products for shielding many parts of the human body. Radiation protection shields (RPS) are external radiation dose reduction equipment available for use during CT to protect the thyroid and mammary glands[12−13]. Although the use of an RPS is known to reduce patient exposure, its effectiveness in reducing scattered dose in the CT room remains undisclosed thus far.

Our objective was to conduct a comparative analysis of scattered dose levels within CT rooms and to evaluate the disparities between employing and not employing RPSs.

MATERIALS AND METHODS

Anthropic phantom

We employed a whole-body human-equivalent phantom (Whole Body Phantom PBU-10; Kyoto Kagaku, Kyoto, Japan). The PBU-10 whole-body phantom is a life-size (height, 150 cm; weight, 50 kg) full body anthropomorphic phantom with state-of-the-art synthetic skeleton, lungs, bronchus, and other parts embedded in the Kyoto Kagaku original soft tissue substitute, without any metal parts or liquid structures. We measured and compared the levels of outside scattered dose experienced with and without the RPS wrapped around the body from the neck to the chest [RADPAD Body Guard for CT; Worldwide Innovations & Technologies Inc., Overland Park, KS, USA] (Fig. 1).

CT imaging

Multi-detector CT studies were conducted using a 64-detector CT scanner (Lightspeed VCT; GE Healthcare, Milwaukee, WI, USA). Scanning was performed in the craniocaudal direction, covering the region from the top of the liver to the lower end of the iliac wing. The scanning parameters included a routine triple-phase CT protocol with a rotation scan duration of 0.5 seconds, a detector row width of 5.0 mm, a helical pitch (beam pitch) of 0.516, a table movement of 41.2 mm, a scan field of view of 50 cm, and tube voltages of 120 kVp with automatic tube current modulation (using a noise index of 10).

Scattered radiation measurement

For the measurement of the scattered radiation dose, we utilised the MY DOSE MINI "X" PDM – 127B-SZ (ALOKA Nippon Ray Tech Company, Limited, Japan). An electronic pocket dosemeter was placed strategically around the CT scanner, as shown in Fig. 2. The scattered dose was measured at intervals of 50 cm from the centre of the gantry. Considering the CT room's layout, a total of 57 points, up to a distance of 200 cm, were measured; these included 28 points in front of the gantry (at the bedside), 6 points on the side of the gantry, and 23 points behind the gantry. These measurements were performed at heights of 50, 100, and 150 cm above the floor surface, corresponding to the estimated locations of the gonads, the mammary glands, and the crystalline lens, respectively. To account for backscattering, the dosemeter was installed with its detection surface facing the centre of the gantry, keeping in mind the directional dependence of the dosemeter (as illustrated in Fig. 3). The scattered dose measurements were compared with and without the RPS. The measured value was obtained as the mean of three measurements. This measured value was input into scattering line distribution map-making software (SS-3000; S. S. Techno-Engineering Corporation, Aichi, Japan) to obtain a scattered radiation distribution map. The scattered dose exposure distributions were compared with and without the RPS.

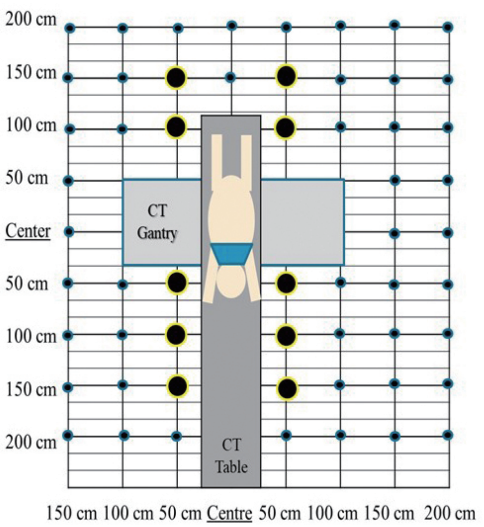

Fig. 2. The electronic pocket dosemeter in the CT room was utilized to measure the radiation levels at 50 cm intervals from the center of the gantry.

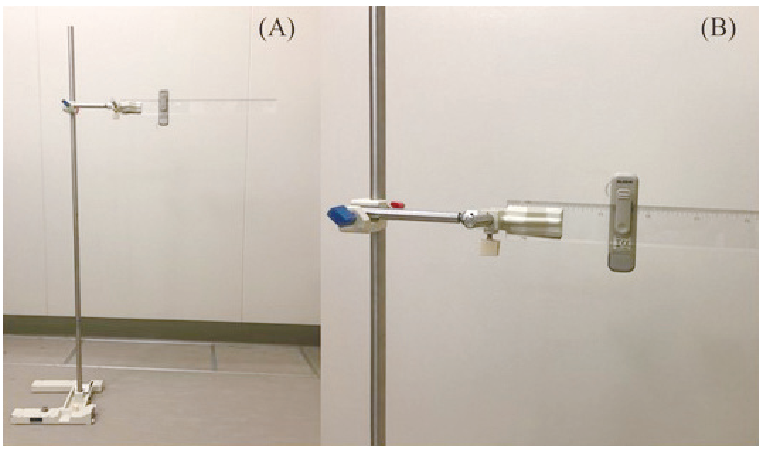

Fig. 3. Installation overview of electronic pocket dosimeter (A) and methods of fixing electronic pocket dosimeter (B).

Table 1. Comparison of the median measurements of the scattered dose with and without the RPS.

		RPS (−)	RPS (+)	p value
150 cm from the back of the CT gantry (μSv)	150 high (cm)	35.4 (31.5 - 38.7)	30.5 (28.8 - 33.0)	< 0.05
	100 high (cm)	17.9 (15.7 - 20.3)	15.0 (13.8 - 16.3)	< 0.05
	50 high (cm)	24.3 (21.8 - 26.7)	22.5 (20.2 - 24.4)	< 0.05
100 cm from the back of the CT gantry (μSv)	150 high (cm)	89.1 (81.5 - 98.4)	73.9 (68.6 - 76.8)	< 0.05
	100 high (cm)	45.1 (40.8 - 50.0)	40.0 (37.5 - 42.5)	< 0.05
	50 high (cm)	57.4 (51.5 - 61.9)	51.6 (47.6 - 56.2)	< 0.05
50 cm from the front of the CT gantry (μSv)	150 high (cm)	186.9 (183.8 - 191.1)	167.3 (157.3 - 181.7)	< 0.05
	100 high (cm)	166.2 (153.9 - 171.4)	158.3 (149.4 - 166.1)	< 0.05
	50 high (cm)	128.1 (125.9 - 135.8)	114.8 (107.5 - 119.6)	< 0.05
100 cm from the front of the CT gantry (μSv)	150 high (cm)	59.5 (56.9 - 65.6)	56.0 (51.3 - 61.1)	< 0.05
	100 high (cm)	36.0 (35.0 - 40.5)	32.9 (30.9 - 33.9)	< 0.05
	50 high (cm)	47.9 (43.9 - 50.9)	41.5 (39.1 - 44.3)	< 0.05
150 cm from the front of the CT gantry (μSv)	150 high (cm)	26.8 (24.3 - 27.7)	22.5 (21.1 - 25.1)	< 0.05
	100 high (cm)	13.4 (13.1 - 14.6)	12.6 (11.6 - 13.4)	< 0.05
	50 high (cm)	7.5 (6.9 - 8.3)	5.4 (5.1 - 5.7)	< 0.05

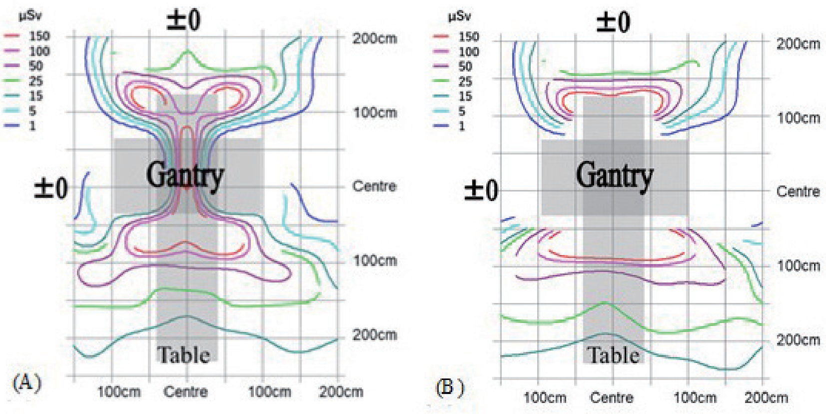

Fig. 4. The dose distribution map for scattered radiation in the in-plane direction within the CT room is depicted for scans with the RPS (A) and without the RPS (B).

Statistical analysis

The measured scattered dose values of the electronic pocket dosemeter were analysed using the Mann-Whitney U test to compare the 'with' and 'without' RPS groups. Statistical significance was defined as $p < 0.05$. All statistical analyses were conducted utilizing the "R" statistical software (version 3.2.2; The R Project for Statistical Computing).

RESULTS

Table 1 shows the comparison of the median scatter dose measurement with and without the RPS. In the 'with RPS' state, the scattered dose was found reduced by approximately 10% for all measurement locations and at the 50, 100, and 150 cm height as well ($p < 0.05$).

The scattered doses exhibited a decrease in values measured for 50 and 150 cm distances from the front of the CT gantry in the order of 150, 100, and 50 cm heights. For all the other measurement points, the scattered doses decreased in the order of 150, 50, and 100 cm heights. In particular, the highest scattered doses were observed at the vertical

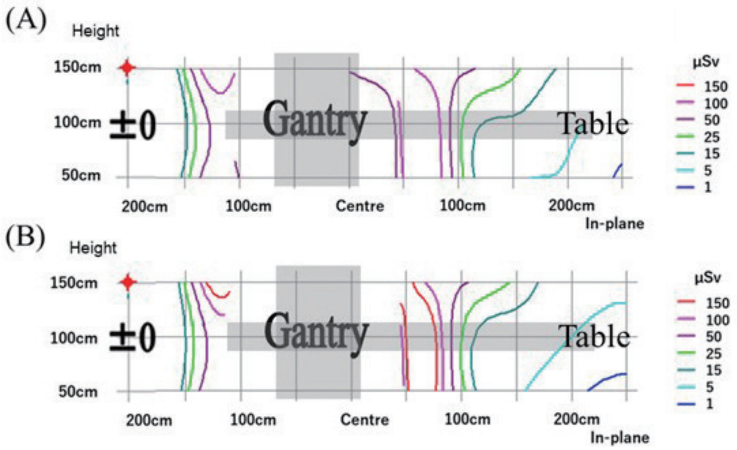

Fig. 5. The dose distribution map for scattered radiation in the vertical direction within the CT room is depicted for scans with the RPS (A) and without the RPS (B).

position of 150 cm, close to the position of the lens.

The distribution map of the scattered dose in the CT room during the in-plane (Fig. 4) and in the vertical direction (Fig. 5), assuming the positions of the lens, the mammary glands, and the reproductive glands, are shown with or without RPS.

DISCUSSION

The scattered dose with the RPS was found reduced by approximately 10% for all measurement locations and for the 50, 100, and 150 cm vertical distances as well.

The RPS not only contributes to the reduction of patient dose, but also effectively decreases the scattered dose in the CT room. Researchers worldwide have reported that the use of RPS during CT imaging can reduce patient radiation exposure doses[12−13]. Therefore, we suggest that it is necessary to use an RPS during CT imaging to support good patient care. According to our results, utilising the RPS could reduce the scattered dose in the CT room during CT examinations. This is the first study to evaluate the scattered dose from CT patients with RPS wrapped around them during the examination.

Importantly, the highest doses of the scattered radiation in our results were observed at the vertical position of 150 cm, close to the position of the lens. According to ICRP Publication 118, the lens of the eye is recognized as one of the most susceptible tissues to radiation-induced damage[14−16]. The established threshold for the development of cataracts, characterised by mild opacity, are reported to be 5 Gy (2 Gy) for acute exposure and 8 Gy (5 Gy) for chronic exposure, while the occurrence was unlikely if the exposure remained below the threshold[17]. However, recent studies have proposed lower thresholds for radiation-induced cataracts[18−19], and even suggest that there might not be a threshold for the occurrence of cataract[20]. The ICRP published Publication 103 in 2007, which reviewed radiation damage to the lens and may release future revisions to the dose limits based on recent data. By using the RPS it would be possible to reduce the scattered dose to the lens dose.

The implementation of the RPS during CT examinations is anticipated to be a straightforward process. The RPS can be easily applied by placing it on the examination bed and securely positioning it around the patient's body. This simple and efficient usage of the RPS not only ensures radiation protection but also offers clinical benefits by enhancing the overall care and well-being of the patient through its protective effects.

However, this study has several limitations. First, this was a phantom experiment, and the results have not been verified through patient assessments. Second, our study was performed using one CT scanner model from a single manufacturer. The relationship between the tube voltage, bowtie filters, and radiation exposure dose may depend, to some degree, on the specifications of the CT scanner under use. Thirdly, the measured scattered dose is outside the protector worn by healthcare workers and is not an estimate of the actual exposure dose.

CONCLUSION

In conclusion, using an RPS reduced the scattered dose by approximately 10% for all measurement locations in comparison with the measurements without an RPS. Using RPS during CT examinations can reduce the scattered dose in CT room.

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CONFLICT OF INTEREST STATEMENT

The authors have no conflict of interest to declare.

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