〈Regular Article〉

Adoption of Radiation Protection Shielding During Head Computed Tomography Imaging to Reduce External Radiation Exposure

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ABSTRACT **Objective**: This study aimed to compare the degree of external radiation exposure experienced by the thyroid and mammary glands based on the presence or absence of a radiation protection shield (RPS) during head computed tomography (CT) imaging.

Methods: We performed an axial head scan using a tissue-equivalent phantom via a 64-detector-row CT scanner. We measured external radiation exposure with and without the RPS at the assumed locations of the thyroid and mammary glands and calculated the mean value by using a calibrated a real-time skin dosimeter. Subsequently, we compared the standard deviation values at the basal ganglia level in the head CT images according to the presence or absence of the RPS.

Results: The levels of external radiation exposure with and without the RPS were 2.42 and 3.61 mGy at the thyroid gland and 0.10 and 0.71 mGy at the mammary glands, respectively. These differences were statistically significant ($p < 0.01$). The RPS facilitated reductions of 32.9% and 86.6% in the mean external radiation exposure at the thyroid and mammary glands, respectively. The standard deviation values of the head CT images at the basal ganglia level were 2.55 ± 0.14 HU and 2.52 ± 0.13 HU with and without the RPS, respectively. Thus, no significant differences in the standard deviation values were observed between measurements with and without the RPS.

Conclusion: The inclusion of an RPS proves effective in reducing external radiation exposure levels during head CT imaging. doi：10.11482/KMJ-E202349087 *(Accepted on November 22, 2023)*

Key words：MDCT, Head CT examination, External radiation exposure, Exposure reduction

INTRODUCTION

In Japan, > 26 million computed tomography (CT) scans are performed annually, impacting approximately one in four citizens. These statistics imply that an estimated 29,000 Japanese individuals may be diagnosed with cancer each year[1-2].

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Head CT imaging is routinely performed on individuals of all ages and genders, from newborns and to older individuals, regardless of sex. The computed tomography dose index volume (CTDIvol), as defined by the diagnostic reference level in each country, is notably higher for head CT at 60 to 85 mGy than for chest and abdomen CTs, which typically range from 15 to 35 mGy[3-5]. Head CT scans subject patients to a considerable external radiation dose, particularly affecting areas such as the thyroid and mammary glands. Therefore, there is a growing concern about potential excessive radiation exposure to these sensitive tissues. Consequently, in accordance with the "as low as reasonably achievable" principle, optimizing radiation protection and minimizing radiation exposure among patients receiving radiation outside the scanning ranges is crucial[6]. However, a consensus is lacking regarding the effects of external radiation exposure on the highly sensitive tissues of the thyroid and mammary glands. In recent years, many manufacturers have marketed radiation protection products for placement around various parts of the human body. A radiation protection shield (RPS) is one such device for external radiation exposure reduction that is available for use during head CT imaging to protect the thyroid and mammary glands. Therefore, this study aimed to compare the external radiation received by the thyroid and mammary glands according to the presence or absence of an RPS during head CT imaging.

MATERIALS AND METHODS

Phantom

We utilized a life-size whole-body human-equivalent phantom (Whole Body Phantom PBU-10; Kyoto Kagaku, Kyoto, Japan) with a height of 150 cm and weight of 50 kg. This phantom consisted of state-ofthe-art synthetic skeleton, lungs, bronchi, and other parts embedded in Kyotokagaku original soft tissue substitutes, and it was devoid of metal components or liquid structures.

CT imaging

Head CT scans were performed using a 64-detector-row CT scanner (LightSpeed VCT; GE Healthcare, Chicago, IL, USA) using the following scanning parameters: axial scan mode, 120 kVp tube voltage, 260-280 mA tube current, 20 mm beam width, full scan mode, 2.0 s gantry rotation time, small bowtie filter, 86.85 mGy CTDIvol, and 1182.46 mGy・cm dose length product. We scanned the phantom a total of five times from the parietal to foramen magnum.

External radiation exposure measurement

External radiation exposure was measured using a calibrated realtime skin dosimeter (RD-1000; Toreck Co., Kanagawa, Japan). We compared the measurement values between the 10 cm ionization chamber and the CTDIvol displayed on the console of the CT equipment to validate the accuracy of this dose. The CTDIvol demonstrated good linearity with the reference dose of the ionization chamber. We also compared the radiation dose between the 10 cm ionization chamber and RD-1000 using X-rays from general radiographic equipment to validate the RD-1000 traceability. The RD-1000 indicated good linearity with the reference dose of the ionization chamber. A dosimeter sensor was installed near the head, where the thyroid and mammary glands were assumed to be highly sensitive to radiation[6]. We measured and compared the levels of external radiation exposure both with and without the RPS encircling the body from the neck to the chest [RADPAD Body Guard for CT (lower abdomen shield); Worldwide Innovations & Technologies Inc., Overland Park, KS, USA] a total of five times (Fig. 1 and 2).

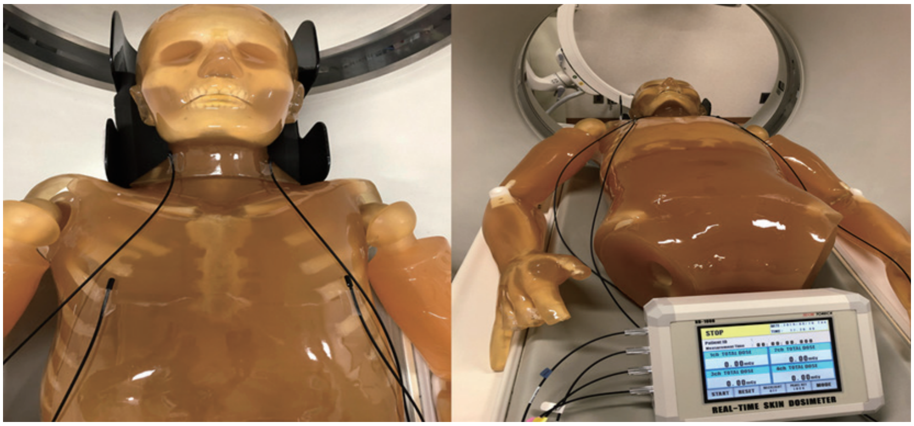

Fig. 1. Measurement setup without the RPS. Dosimeter sensors were positioned on both sides of the thyroid and mammary glands.

Fig. 2. Measurement setup with the RPS. Measurements were conducted with the RPS encircling the body from the neck to the chest.

Image analysis

To assess the impact of the presence or absence of the RPS on CT image quality, we measured and compared the standard deviations of the CT numbers (Hounsfield Units, HU) on a CT console monitor. These measurements were taken within circular regions of interest with diameters ranging from 10-20 mm, placed at the level of the basal ganglia during head CT imaging.

Statistical analysis

To compare external radiation exposures with and without the RPS, we employed the Mann-Whitney U test. Values of $p < 0.01$ were considered statistically significant. Statistical analyses were conducted using free statistical software (version 3.0.2, The R Project for Statistical Computing, http://www.rproject.org/; The R Foundation for Statistical Computing, Vienna, Austria).

RESULTS

The mean levels of external radiation exposure with and without the RPS were as follows: 2.34 ± 0.02 mGy (with RPS) and 3.49 ± 0.21 mGy (without RPS) for the right side of the thyroid gland and 2.51 ± 0.01 mGy (with RPS) and 3.73 ± 0.25 mGy (without RPS) for the left side. This indicates a notably higher radiation exposure on the left side. The mean external radiation exposures for both sides of the thyroid gland were 2.42 ± 0.01 mGy (with RPS) and 3.61 ± 0.23 mGy (without RPS) (Fig. 3). These findings suggest a significant difference in the radiation exposure levels with and without the RPS ($p < 0.01$), with the mean external radiation exposure being 32.9% lower with the RPS (Table 1).

The mean external radiation exposures with and without the RPS were as follows: 0.11 ± 0.01 mGy (with RPS) and 0.73 ± 0.17 mGy (without RPS) for the right mammary gland and 0.08 ± 0.01 mGy (with RPS) and 0.69 ± 0.17 mGy (without RPS) for the left mammary gland. This indicates a significantly higher radiation exposure for the right mammary gland. Meanwhile, the mean external radiation exposure for both mammary glands was 0.10 ± 0.01 mGy (with RPS) and 0.71 ± 0.17 mGy (without RPS) (Fig. 3). A significant difference was observed in the mean external radiation exposure with and without the RPS ($p < 0.01$), with the mean external radiation exposure being 86.6% lower with the RPS (Table 1).

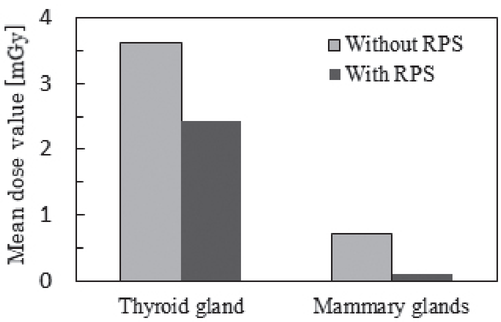

Fig. 3. Comparison of mean radiation dose to the thyroid and mammary glands with and without the RPS.

The standard deviation values for the head CT images at the basal ganglia level were as follows: 2.55 ± 0.14 HU (with RPS) and 2.52 ± 0.13 HU (without RPS). No significant differences were observed in the standard deviation values with and without the RPS.

DISCUSSION

The incorporation of an RPS during head CT imaging demonstrated a significant reduction in the radiation exposure to the thyroid and mammary glands.

In 2007, the International Commission on Radiological Protection (ICRP) recommended raising the tissue-weighting factor for mammary glands from 0.05 to 0.12[7]. Therefore, we aimed to establish updated patient educational materials to minimize external radiation exposure. The utilization of an RPS serves to safeguard patients from radiation exposure. In particular, we must understand the nature of external radiation exposure during head CT examinations to enhance patient care and well-being.

This study reveals a substantial decrease in external radiation exposure when utilizing the RPS. Our findings indicate that the level of

Table 1. Mean radiation dose outside the scanning area with and without the RPS

		Without RPS (mGy)	With RPS (mGy)	Significant difference	Reduction rate (%)
	Right side	3.49 ± 0.21	2.34 ± 0.02		
Thyroid gland	Left side	3.73 ± 0.25	2.51 ± 0.01	$p < 0.01$	32.9
	Mean side	3.61 ± 0.23	2.42 ± 0.01		
	Right side	0.73 ± 0.17	0.11 ± 0.01		
Mammary glands	Left side	0.69 ± 0.17	0.08 ± 0.01	$p < 0.01$	86.6
	Mean side	0.71 ± 0.17	0.10 ± 0.01		

external radiation exposure experienced without the RPS was significantly higher than that with the RPS. Researchers worldwide have reported that RPS use during CT imaging can reduce radiation exposure[8−10]. However, to the best of our knowledge, this study is the first to quantify external radiation exposure during head CT. Hence, we advocate the essential adoption of RPS during head CT imaging to promote optimal patient care. The reduction rate in radiation exposure to the mammary glands was more pronounced than that of the thyroid gland when employing the RPS. This phenomenon is attributed to the attenuation of X-ray energy by the RPS, as X-ray energy diminishes with increased distance from the scanning site. Moreover, proximity to the scanning site results in more significant internal scattering. Therefore, the use of an RPS is also beneficial for protecting against external radiation exposure to other areas of the body.

The implementation of an RPS is expected to be straightforward for routine CT examination. Using the RPS during CT imaging involves placing it on a bed and then wrapping it around the patient. Its use will also provide clinical benefits for patient care due to its protective effect.

Nonetheless, our study had several limitations. First, this study was a phantom experiment, and its results have not been validated through patient assessments. Second, our studies were performed using a single CT scanner model from a single manufacturer. The relationship between the tube voltage, bowtie filters, and radiation exposure dose may, to some extent, depend on the specifications of the CT scanner being used.

CONCLUSION

An RPS is effective in reducing radiation exposure to the thyroid and mammary glands during head CT examination.

FUNDING

This study received no commercial interests or financial and / or commercial support.

CONFLICT OF INTEREST STATEMENT

The authors have no conflict of interest to declare.

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