RAD

Exposure Dose to Neonates, Operators and Attendants Using MobileDaRt Evolution

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1. Introduction

It is well known that chest X-ray imaging plays a very important role in the diagnosis of chest lesions in neonates[1]. However, concerns exist that the exposure of neonatal patients to increasing quantities of radiation through imaging will increase the future risk of cancer development. Additionally, the exposure dose received by the operator and attendants is also of concern, as they often stand very close to the neonatal patient when mobile X-ray system is used in an NICU (neonatal intensive care unit). As a result, in recent years there has been increased interest in the exposure dose received from chest X-ray imaging by neonates, operators and attendants. There is a demand for the precise assessment of exposure dose based on experimental measurements.

The spread of digital X-ray system equipped with an FPD has increased remarkably, with an increasing use of mobile digital X-ray system in the NICU. There are many advantages to using digital X-ray system, including the reduced time to image display and increased image quality. Fig. 1 shows the MobileDaRt Evolution mobile digital X-ray system, made by Shimadzu and equipped with a Canon CXDI-60C flat panel detector (FPD). The MobileDaRt Evolution has been shown in reports to exhibit excellent performance in terms of operability and image quality[2]. In this study, we measured and evaluated quantitatively the exposure dose to neonatal patients and the surroundings (operators and attendants) during chest X-ray imagining with the MobileDaRt Evolution, and examined whether the exposure dose can be reduced. This article will give a brief explanation of this study that can be examined in more detail by referring to the original article[3].

Before measuring exposure dose, we investigated the basic characteristics (digital characteristics) of the FPD. After this, a patient skin dosimeter (PSD) was placed on a phantom that represented a neonate. The exposure dose to the neonatal patient was measured and the dependency of exposure dose on imaging conditions was investigated. Next, we recreated as far as possible the conditions present during the actual imaging of neonates when placed within an incubator (Incu i, Atom Medical Corporation) in an NICU and used a survey meter to measure exposure dose around the incubator during X-ray imaging and estimate the exposure dose to the operator. The system used during experimentation was a MobileDaRt Evolution (Shimadzu Corporation) equipped with an FPD (CXDI-60C, Canon). The MobileDaRt Evolution is capable of imaging in a tube voltage range of 40–133 kV and mAs parameter range of 0.32–320 mAs. The CXDI-60C FPD uses CsI as a scintillator, and has 1464 × 1776 pixels and a maximum image size of 23 cm × 28 cm.

The study presented in this article was conducted as joint research with associate professor Hajime Monzen and others of the Medical Physics Group of Kyoto University during my tenure in the Graduate School of Medicine at Kyoto University.

Fig. 1

2. Digital Characteristics

In a study to determine the digital characteristics of MobileDaRt Evolution, an Unfors PSD was placed 15 cm away from the FPD in the direction of the X-ray tube of the MobileDaRt Evolution and the exposure dose was measured. The tube voltage, mAs parameter and pixel value of the image (average pixel value of a 100 × 100-pixel area at the center of the image) were also recorded for each measurement. Measurements were taken distant from the FPD to avoid the intrusion of backscatter components. The distance between the X-ray tube and the FPD was a constant 90 cm.

Experimental results are shown in the graph in Fig. 2. Exposure dose (μGy) measured using the PSD is plotted on the horizontal axis on a logarithmic scale and the pixel value is plotted on the vertical axis. The numbers on the curves are the mAs values used during imaging, where the mAs parameter was varied by set intervals in the range 0.32–3.2 mAs between measurements. The tube voltage was varied by set intervals between 50 and 110 kV with the measurements taken at each tube voltage plotted on the graph with different color lines. Changing the tube voltage resulted in almost no change in curve slope, showing that image contrast characteristics were almost unaffected by tube voltage where good linearity was achieved at even small tube voltages and mAs values. The pixel value increased with increasing tube voltage and exhibited an upper limit close to 3700, as shown on the graph.

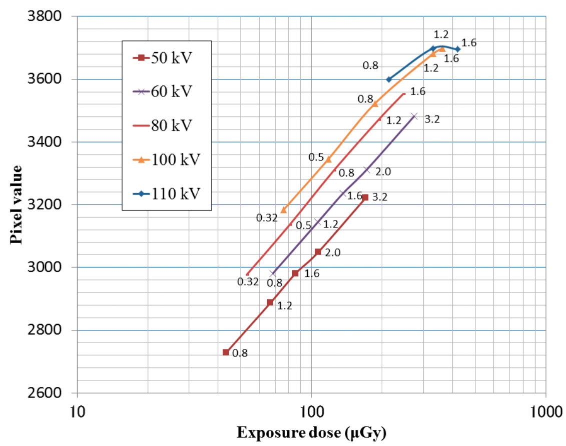

Fig. 2

3. Entrance-Surface Dose to the Neonatal Patient

To measure the entrance-surface dose (skin dose) to neonatal patients during chest X-ray imaging, a PSD was attached to the surface of a phantom (30 cm × 30 cm in size) that represented the neonatal patient, and exposure dose was measured. During imaging, the mAs parameter was set at 0.8 mAs that is commonly used for chest X-ray imaging, and the tube voltage and phantom thickness were varied (phantom thickness was varied at 4.5, 5.0, 6.0, 7.0 and 8.0 cm and imaging performed at each thickness at tube voltages of 53, 54, 56, 58 and 60 kV). Phantom thickness and tube voltage were varied because tube voltage is normally increased in neonatal patients with a larger body thickness.

Experimental results are shown in the graph in Fig. 3. The entrance-surface dose in a neonatal patient is plotted for exposure fields of 12 × 12 cm and 19.5 × 12.5 cm. These exposure field sizes are expected exposure field sizes used during chest and thoraco-abdominal imaging in a neonatal patient. Phantom thickness (cm) is plotted on the horizontal axis and entrance-surface dose (μGy) is plotted on the vertical axis. The results show a small difference (2–3 %) in entrance-surface dose between the two exposure field sizes. The maximum entrance-surface dose measured was 51–52 μGy (phantom thickness of 8.0 cm) and the minimum entrance-surface dose measured was 33–34 μGy (phantom thickness of 4.5 cm). The results confirm a well-known characteristic that increasing phantom thickness causes an increased backscatter component, and consequently an increased entrance-surface dose. Past studies have measured the entrance-surface dose during chest X-ray imaging in neonatal patients under various conditions. Our results obtained in the present study are either equivalent to or lower than the results obtained in those previous studies[4), 5), 6)].

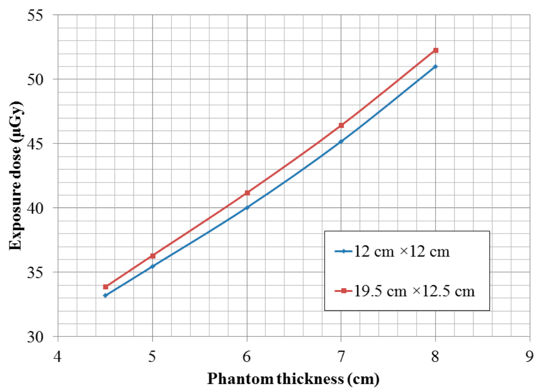

Fig. 3

4. Exposure Dose to the X-Ray Operator and Attendants

Experiments were performed to measure the exposure dose to X-ray operators and attendants during chest X-ray imaging. X-ray imaging was performed using a phantom placed inside an incubator (Incu i, Atom Medical Corporation) to recreate as far as possible actual conditions during imaging. Using a survey meter (451B-DE-SI, Fluke Biomedical), exposure dose was measured at various orientations, distances, and heights around the incubator. Imaging conditions were fixed at settings commonly used in actual clinical practice (exposure field size of 12 × 12 cm, 0.8 mAs, tube voltage of 80 kV). A phantom thickness of 8.0 cm was used to estimate upper limit of scatter in a neonatal patient. Measurements were taken at the positions shown in Fig. 4. Taking the arm of the MobileDaRt Evolution as zero degrees from the point of view of the phantom, measurements were performed at positions at 45, 90, 135, 180, 225 and 315 degrees in a clockwise direction. (Measurements were performed at 30, 45 and 60 cm from the center of the exposure field and at 100 and 130 cm from the floor.)

Exposure dose measurements performed around the incubator are shown in Table 1. Results are only shown at distances from the center of the exposure field that exhibited the highest measured exposure dose for each direction (also applied for the distances shown in text boxes in Fig. 4). While an exposure dose of 0.6 μSv was measured at a position 130 cm from the floor in the A1 direction, the exposure dose was low in all positions and at no position was higher than 1 μSv during a single X-ray imaging.

The directional dependency shown in the exposure dose measurement results in Table 1 is believed to be the effect of the relative positions of the incubator and MobileDaRt Evolution. Since we did not minimize exposure dose through optimization of imaging conditions in this experiment, the actual exposure dose received by the operator is very likely to be lower than those shown in Table 1.

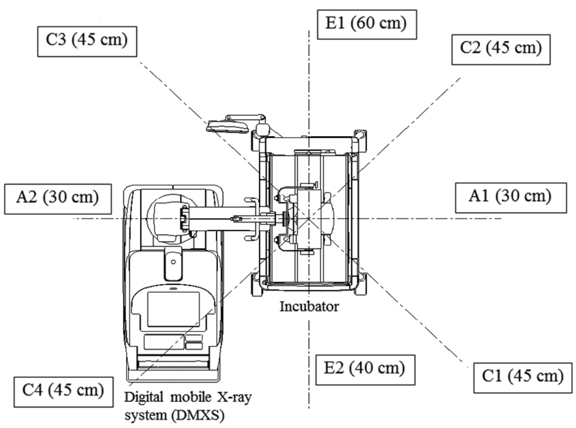

Fig. 4

Level from ground	A1 (30 cm)	A2 (30 cm)	C1 (45 cm)	C2 (45 cm)	C3 (45 cm)	C4 (45 cm)	E1 (60 cm)	E2 (40 cm)
100 cm	0	0.1	0	0	0	0.1	0	0.1
130 cm	0.6	0.1	0	0.1	0.1	0.3	0	0.1

Table 1

5. Conclusion

In this study, the MobileDaRt Evolution (equipped with a CXDI-60C FPD) exhibited good digital characteristics. The entrance-surface dose to the neonatal patient undergoing chest X-ray imaging was equivalent or lower than the results of previous studies, and the exposure dose to the operator and attendants was very low. The exposure doses indicated in this study could also be reduced further by fine image quality assessment and optimization of imaging conditions. Based on these results, it can be stated that compared with previous imaging methods, using the MobileDaRt Evolution is very likely to result in a lower entrance-surface dose in neonatal patients and lower exposure dose to the operator. Progress in digital imaging technology has not been limited to technical advances such as improvements in image quality, but has also advanced digital imaging as a powerful tool for the conduct of medical care that is safe both to the patient and the medical practitioner.

References

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