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Radiation dose reduction in pediatric CT

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Abstract. The relationship between image noise and radiation dose was investigated in computed tomography (CT) images of a pediatric abdomen phantom. A protocol which provided a minimum absorbed dose consistent with acceptable image noise criteria was determined for a fourth generation CT scanner. It was found that pediatric abdominal CT scans could maintain diagnostic quality with at least a 50% reduction in dose from the manufacturers' suggested protocol.

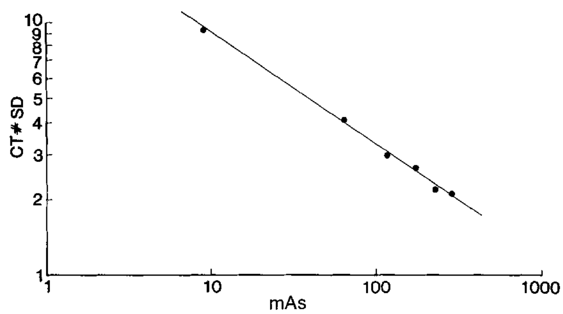

Fig. 1. Plot of standard deviation of CT number vs mA

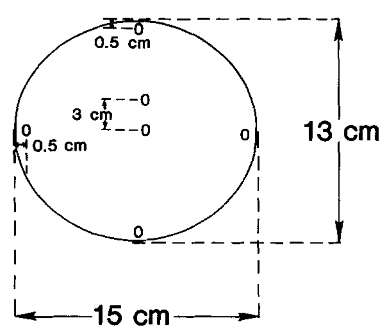

Fig. 2. Cross-section of pediatric abdomen phantom

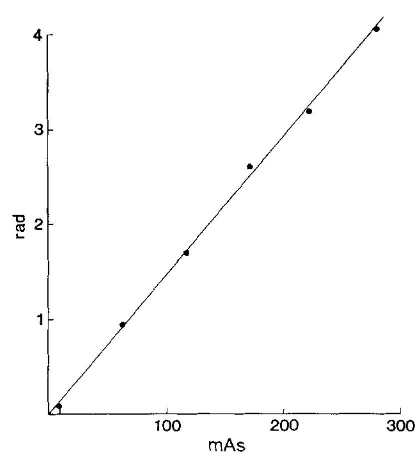

Fig. 3. Plot of absorbed dose at center of pediatric phantom vs mAs

Typical manufacturers preprogrammed protocols for pediatric abdomen CT examinations (i. e. 130 KVP at 210 mAs with 256 × 256 matrix) were designed to produce images with low noise but with center line absorbed dose levels of almost 3 rad. Reducing scanning factors to lower absorbed dose, however, must necessarily increase noise content of the CT image, if other indicators of image quality are held constant [1-3]. The purpose of the present investigation was to directly determine the dependence of image noise on absorbed dose in pediatric patients and suggest to what extent exposure factors could be reduced while still yielding images within acceptable noise levels.

Methods and results

The Victoreen-AAPM Test Object (Victoreen, Nuclear Associates, Carle Place, NY) with water insert was scanned with a Picker 600 CT (Picker International, Cleveland, OH) unit at 130 KVP, extended scan angle of 398°, and scan time of 1.8 s for tube currents of 5, 35, 65, 95, 125 and 155 mA at 10-mm slice increments to simulate abdominal CT images. The images were reconstructed using a high resolution algorithm on a 256 × 256 image matrix. The image noise, taken as the standard deviation (SD) of the CT numbers from regions of interest in areas of pure water, was plotted against mAs (Fig. 1) and was seen to yield a straight line in accordance with theory [3] with a slope approximately 10% less than the theoretical slope of 0.5. The regression equation being

$$\log SD = -0.44 \log mAs + 1.39, r = 0.99 \quad (1)$$

A pediatric CT phantom was constructed of tissue equivalent plastic with 13 x 15 cm cross sectional dimensions (Fig. 2). The phantom was 10 centimeters thick and had small cavities to accomodate thermal luminescent dosimeters (TLD) for determination of absorbed dose. The TLD's used were of the CaF_2 type which were standardized against a Victoreen air chamber (F3) at diagnostic X-ray energies and read in a Capintec (Capintec Systems, Inc., Ramsey, NJ) TLD reader.

The absorbed dose at the center of the phantom was plotted against mAs and was seen to fall along an expected straight line (Fig. 3).

Taking the standard deviation of the CT numbers within a cursor area as the expression of noise, Eq. (1) and the plot between dose and mAs (Fig. 3) allowed a relation to be deduced between noise and absorbed dose:

$$\log \text{Noise} = -0.44 \log \text{Dose} + 0.565 \quad (2)$$

Discussion

All devices, medical or otherwise, are distributed with operating instructions which reflect the limits of the machinery, regulations, or optimization of output. Imaging equipment is no exception. With imaging devices that emit ionizing radiation, image optimization may be limited by the practical capabilities of the image source or regulations which limit radiation dose to the patient. However, stricter guidelines are often considered important for the pediatric patient in order to limit radiation exposure to the minimal level required for diagnosis.

CT scanners are distributed with built-in preset protocols, but many of these techniques designed for optimal image quality subject patients to radiation dosages that are higher than other procedures. It is not uncommon for preset protocols to be accepted as they are received without attempts to lower the radiation exposure for fear that technical quality will be sacrificed.

Brasch and Gann [4] noted considerable improvement in both resolving power and radiation dose reduction from the early days of body scanning to the present day utilization of third and fourth generation scanners. However, third generation scanners with longer scan times revealed lower patient radiation exposure than fourth generation units tested. If it can be considered that scan time capabilities less than 2 s are more suitable for pediatric studies, a higher radiation dose level is disturbing.

Haaga et al. [5] described a method for optimization of CT images with reduced radiation dosage. They evaluated low contrast resolution to determine CT noise as the standard deviation of a fixed region of interest in the presence of a homogeneous image density. This standard deviation of CT density was obtained by centering a cursor area within a representative area of the patient's body image. A subjective value of 10 HU standard deviation was found to be acceptable for image quality.

Modifying Haaga's suggestions of an acceptable image noise figure down to four CT units for pediatric abdominal studies, in the present circumstances, would result in an exposure of roughly 60 mAs and an absorbed dose of 0.9 rad in the mid-line, less than one third that of the preset protocol. Scans made at these reduced exposure factors are now routine for pediatric patients at our institution and result in images with signal to noise ratios acceptable for interpretation. We recommend that other institutions consider similar means to determine the minimum dose required to produce acceptable images in pediatric CT imaging.

References

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