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Increased Computed Tomography Dose Due to Miscentering With Use of Automated Tube Voltage Selection: Phantom and Patient Study

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The purpose of the article is to determine if miscentering affected dose with use of automated tube voltage selection software. An anthropomorphic phantom was imaged at different table heights (centered in the computed tomography [CT] gantry, and −6, −3, +3, and +5.7 cm relative to the centered position). Topogram magnification, tube voltage selection, and dose were assessed. Effect of table height on dose also was assessed retrospectively in human subjects ($n = 50$). When the CT table was positioned closer to the x-ray source, subjects appeared up to 33% magnified in topogram images. When subjects appeared magnified in topogram images, automated software selected higher tube potentials and tube currents that were based on the magnified size of the subject rather than the subject's true size. Table height strongly correlated with CT dose index ($r = 0.98$, $P < 0.05$) and dose length product ($r = 0.98$, $P < 0.05$) in the phantom study. Transverse dimension in the topogram highly correlated with dose in human subjects ($r = 0.75$-0.87, $P < 0.05$). Miscentering results in increased dose due to topogram magnification with automated voltage selection software.

Introduction

Automated tube voltage selection is a computed tomography (CT) dose reduction tool that can reduce patient dose by 18%-40%.[1-7] Tube voltage selection software utilizes information in topogram images to determine tube voltage based, in part, on patient size and attenuation in the topogram image.[7] Miscentering the patient in the CT gantry results in magnification in the topogram if the patient is positioned closer to the x-ray source.[8,9] Prior investigations have found that magnification in the topogram results in increased radiation dose when tube current selection is based on patient size in topogram images.[8,9] To our knowledge, the effect of magnification in the topogram image on tube voltage selection has not been reported previously.

The purpose of this investigation was to determine if miscentering affected dose with use of automated tube voltage selection software. We conducted a phantom study as well as a retrospective patient study.

Materials and Methods

Phantom Study

The phantom used was a modified Livermore phantom (Pacific Northwest National Lab, Richland, WA) of the thorax and abdomen (Fig 1).[10-12] The phantom simulates a male cadaver anthropomorphically, who was 1.77 m in height, 75 kg in weight, and 1.01 m in chest circumference.[11] The major organs, including heart, lung, liver, kidney, ribs, muscle, and adipose tissue, were duplicated with tissue-equivalent substitutes.[11]

To center the phantom in the gantry, the anterior-posterior midpoint of the phantom was identified, and the laser lights of the CT gantry were aligned with this midpoint. Images were acquired with the phantom centered in the CT gantry as well as at −6, −3, +3, and +5.7 cm relative to the centered position. The +5.7 cm position was the highest possible table position.

Images were acquired using the Siemens Somatom Definition Flash and CARE kV and CARE Dose 4D with parameters as reported in Table 1. The workflow for CARE kV and CARE Dose 4D has been described previously.[1-3,7,13,14] CARE kV tube potential modulation adjusts tube potential based on patient size and attenuation as determined based on the topogram, the user-selected indication for the study, and the user-selected reference (ref) kV.[2] Tube potentials typically selected by CARE kV are 80, 100, 120, or 140 kV.[1-3]

CARE Dose 4D is a combined size-based and angular (x-y axis) method of tube current modulation.[14] The size-based portion of the algorithm utilizes the user-selected image quality ref Milliampere-second (mAs) value and the user-selected adaptation strength.[14] Topogram information is used to determine if the patient's anatomy is slim or obese compared to stored values for a standard size patient.[14] The user-selected adaptation strength (strong, average, or weak) for each combination of size (slim or obese) and anatomic location (eg, abdomen or pelvis) is then used to, in part, determine tube current.[14] Additionally, with CARE Dose 4D, tube current is altered in real time with angular (x-y axis

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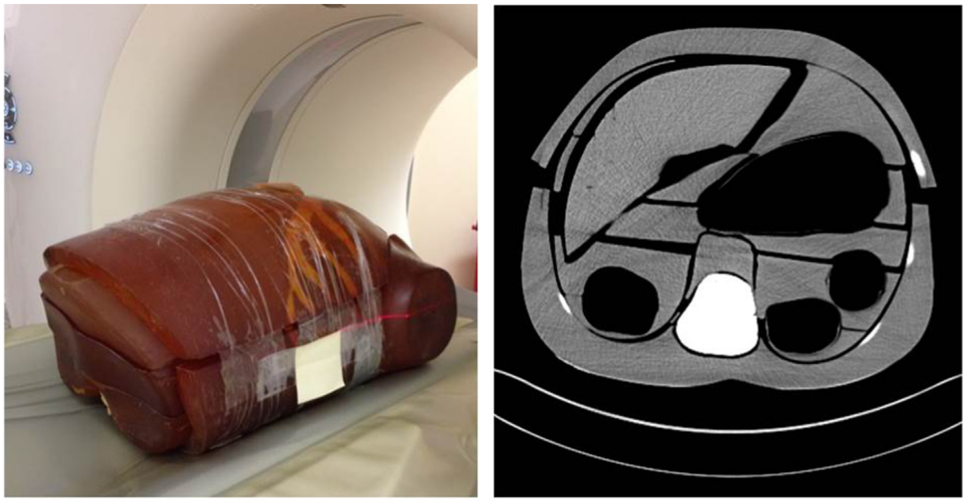

Fig. 1. Modified Livermore phantom. (A) Photograph of the modified Livermore phantom in the CT gantry. (B) Axial computed tomographic image of the modified Livermore phantom. (Color version of figure is available online.)

modulation) whereby the actual attenuation of the patient is measured during the scan and tube current is adjusted accordingly.

The frontal topogram was obtained with the x-ray source in the posterior-anterior position, as this was the standard practice at our institution at the time of this study. Phantom transverse dimension was measured at the level of the liver in all frontal topograms and in the corresponding axial CT image. Tube voltage, volume computed tomography dose index ($CTDI_{vol}$), dose length product (DLP), and mAs/ref were recorded from the dose report page.

Retrospective Patient Study

Institutional Review Board approval was obtained, and a waiver of informed consent was granted for this Health Insurance Portability and Accountability Act compliant study.

The Emory University Hospital Midtown (Atlanta, Georgia USA), abdominal CT worklist was reviewed retrospectively, and 50 consecutive patients who underwent 2 single-phase CT scans of the abdomen and pelvis with intravenous contrast material in the portal venous phase of enhancement performed on the same machine and with the same software were recorded. The follow-up scan that occurred closest in time to the initial scan was included in the analysis.

Table 1
User-selected scan parameters. Reference tube potential (kV) is selected to match routine clinical practice.[7] Quality reference mAs defines the effective mAs needed to produce a specific image quality.[13] Imaging application setting (1-12) is based on the diagnostic task. Adaptation strengths refer to how tube currents are adjusted based on patient size in the topogram as compared to internally stored attenuation values[14]

Parameter	Value
Reference kV	120
Quality reference mAs	206
Imaging application setting	7
Care dose 4D adaptation strengths	
Adult slim abdomen	Weak
Adult obese abdomen	Very strong
Adult slim pelvis	Weak
Adult obese pelvis	Strong
Slice thickness (mm)	4
Table speed (mm/rot)	46
Spiral pitch factor	0.6

Patient sex, age, kVp, $CTDI_{vol}$, DLP, and mAs/ref were recorded. Table height was recorded from the Digital Imaging and Communication in Medicine header. Table height was selected by the technologist for each patient scan. Technologists were instructed to center individual patients based on a visual estimate of the midpoint of the patient's anterior-posterior dimension.

To evaluate for magnification in the frontal topogram, the patient's transverse dimension was measured in the frontal topogram at the level of the liver. The corresponding axial image was identified by using the cross-reference tool, and the subject's maximal transverse diameter was measured in the corresponding axial image. The percentage magnification in the topogram was computed using the following formula: (transverse diameter in topogram image-transverse diameter in axial image) divided by transverse diameter in axial image $\times$ 100%.

Statistical Analysis

Statistical analysis was performed using SAS version 9.3 (SAS Institute, Cary, NC). Pearson correlation coefficients were computed. The Wilcoxon sum rank 2-sample test was used to test differences in means. $P < 0.05$ was considered significant.

Results

Phantom Study

Table height, transverse dimension, phantom magnification in topogram, mAs/ref, kV, $CTDI_{vol}$, and DLP are reported in Table 2.

Table Height and Topogram Magnification

Table height was highly correlated with magnification in the frontal topogram ($r = 1.0, P < 0.05$). Measured transverse phantom diameter in the topogram ranged from 342-430 mm depending on table height (Table 2). Actual phantom transverse diameter as measured in the corresponding axial image was 334 mm.

Percentage magnification in the posterior-anterior topogram ranged from 2.4%-31.1% and correlated with table height ($r = 1.0$, $P < 0.05$). In other words, the closer the table position was to the x-ray source, the more magnified the phantom appeared in the frontal topogram (Fig 2).