Original Investigations

Automated Tube Voltage Adaptation in Combination with Advanced Modeled Iterative Reconstruction in Thoracoabdominal Third-Generation 192-Slice Dual-Source Computed Tomography:

Effects on Image Quality and Radiation Dose

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Abbreviaitons

ADMIRE advanced modeled iterative reconstruction; **AP** anterior-posterior; **CNR** contrast-to-noise ratio; **CT** computed tomography; **$CTDI_{vol}$** CT dose index volume; **DSCT** dual-source computed tomography; **FBP** filtered back projection; **HU** Hounsfield units; **ICC** intraclass correlation coefficient; **LAT** lateral; **ROI** region of interest; **SD** standard deviation; **SNR** signal-to-noise ratio; **SSDE** size-specific dose estimates; **TCM** tube current modulation; **TVA** tube voltage adaptation

Rationale and Objectives: To evaluate image quality and radiation exposure of portal venous–phase thoracoabdominal third-generation 192-slice dual-source computed tomography (DSCT) with automated tube voltage adaptation (TVA) in combination with advanced modeled iterative reconstruction (ADMIRE).

Materials and Methods: Fifty-one patients underwent oncologic portal venous–phase thoracoabdominal follow-up CT twice within 7 months. The initial examination was performed on second-generation 128-slice DSCT with fixed tube voltage of 120 kV in combination with filtered back projection reconstruction. The second examination was performed on a third-generation 192-slice DSCT using automated TVA in combination with ADMIRE. Attenuation and image noise of liver, spleen, renal cortex, aorta, vena cava inferior, portal vein, psoas muscle, and perinephric fat were measured. Signal-to-noise ratio (SNR) and contrast-to-noise ratio (CNR) were calculated. Radiation dose was assessed as size-specific dose estimates (SSDE). Subjective image quality was assessed by two observers using five-point Likert scales. Interobserver agreement was calculated using intraclass correlation coefficients (ICC).

Results: Automated TVA set tube voltage to 90 kV (n = 8), 100 kV (n = 31), 110 kV (n = 11), or 120 kV (n = 1). Average SSDE was decreased by 34.9% using 192-slice DSCT compared to 128-slice 120-kV DSCT (7.8 $\pm$ 2.4 vs. 12.1 $\pm$ 3.2 mGy; $P < .001$). Image noise was substantially lower; SNR and CNR were significantly increased in 192-slice DSCT compared to 128-slice DSCT (all $P < .005$). Image quality was voted excellent for both acquisition techniques (5.00 vs. 4.93; $P = .083$).

Conclusions: Automated TVA in combination with ADMIRE on third-generation 192-slice DSCT in portal venous–phase thoracoabdominal CT provides excellent image quality with reduced image noise and increased SNR and CNR, whereas average radiation dose is reduced by 34.9% compared to 128-slice DSCT.

Key Words: Computed tomography; automated tube voltage adaptation; radiation dose; image quality.

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Contrast-enhanced computed tomography (CT) is a well-established cross-sectional imaging technique in oncologic patients (1). Because CT may account for majority substantial amount of radiation exposure in oncologic patients (2), new technical innovations have focused on improvement of image quality and further radiation dose reduction to keep radiation dose “as low as reasonably achievable” (3).

Several techniques for radiation dose reduction have been proposed (4–11). Tube current modulation (TCM) adapts tube current to the body’s anatomy in real-time and is activated on most currently available CT systems (12–14). Tube voltage reduction is another promising technique for radiation dose reduction and can be performed using automated attenuation-based software (5,6,9–11). A potential drawback of low–tube-voltage acquisition is an increase in image noise, which may impair diagnostic image quality. Therefore, manual adjustment of tube voltage on an individual basis may be challenging. Automated tube voltage adaptation (TVA) can adapt tube voltage to the patient body based on attenuation measurements, maintaining sufficient image quality, even in low-kilovoltage examinations. Furthermore, the application of iterative reconstruction (IR) techniques can substantially reduce image noise (4,15–17).

The purpose of our study was to intraindividually evaluate image quality and radiation dose of thoracoabdominal portal venous–phase third-generation 192-slice dual-source CT (DSCT) using automated TVA and advanced modeled iterative reconstruction (ADMIRE) compared to 120-kV second-generation 128-slice DSCT. We evaluated oncologic patients who had undergone subsequent CT on both DSCT systems.

MATERIALS AND METHODS

Patient Population

This retrospective study was approved by the ethics committee of our hospital, and the requirement for written informed consent was waived. We evaluated patients who had been examined in the context of their regular oncologic thoracoabdominal follow-up CT examinations between March and November 2014. The 192-slice DSCT system was installed at our institution in August 2014. We solely included patients who had undergone CT on both 128-slice and 192-slice DSCT during that time frame. Inclusion criteria were clinically indicated routine contrast-enhanced follow-up CT in portal venous phase without interim surgery, radiation therapy, or chemotherapy. Emergency cases, CT angiography, and noncontrast examinations were excluded from this study. Further exclusion criteria were any known allergies to iodinated contrast medium, patients <18 years, renal impairment with a glomerular filtration rate <60 mL/min, and known pregnancy.

Examination Protocol

The initial CT examination (examination A) was performed on a 128-slice second-generation DSCT system (SOMATOM Definition Flash; Siemens Healthcare, Forchheim, Germany) with a fixed tube voltage of 120 kV and 210 reference mAs. Dedicated mAs-modulation software (CARE Dose 4D; Siemens Healthcare) was used to automatically set tube current in real time to reduce radiation dose. Further scan parameters were as follows: pitch, 0.8; rotation time, 1.0 seconds; collimation, 128 × 0.6 mm. The second CT examination (examination B) was performed on a 192-slice third-generation DSCT scanner (SOMATOM Force; Siemens Healthcare) with automated TVA (CarekV; Siemens Healthcare). On the basis of the patient’s anatomy, automated TVA selected the optimal tube voltage between 70 and 150 kV in steps of 10 kV. The reference imaging protocol was set to 147 mAs at 120 kV, and TCM (CARE Dose 4D) was activated. Further scan parameters were as follows: pitch, 0.6; rotation time, 0.5 seconds; collimation, 192 × 0.6 mm.

All CT examinations were acquired in craniocaudal direction with the patient in supine position and in inspiratory breath-hold. Data acquisition started 85 seconds after start of intravenous administration of 90 mL of nonionic iodinated contrast medium (iopamidol, Imeron 400; Bracco, Konstanz, Germany) with a flow rate of 3 mL/sec.

Image series of 128-slice DSCT were reconstructed using filtered back projection (FBP) algorithm with a soft tissue convolution kernel (B30f). The 192-slice DSCT image series were reconstructed using third-generation IR (ADMIRE; Siemens Healthcare) with a strength level 3 of 5 and a soft tissue convolution kernel (Br40). For both CT examinations, all data sets were reconstructed as axial image series with a slice thickness of 3 mm (1.5-mm increment).

Radiation Dose Estimation

Radiation exposure was expressed as CT dose index volume ($CTDI_{vol}$) provided by the patient’s protocol. The effective diameter of the trunk was measured from the anterior–posterior (AP) and lateral (LAT) dimension at the liver hilum.

$$effective\ diameter\ (cm) = \sqrt{AP \times LAT}$$

To calculate size-specific dose estimates (SSDE), a conversion factor based on the effective diameter and the 32-cm diameter PMMA phantom provided by the AAPM report No. 204 was selected in each patient (18).

$$SSDE\ (mGy) = CTDI_{vol} \times conversion\ factor$$

Objective Image Quality Analysis

All measurements were performed on a commercially available picture archiving and communication system (PACS) workstation (Centricity 4.2; GE Healthcare, Dornstadt, Germany). The following anatomic structures were evaluated: liver, spleen, renal cortex, perinephric fat, psoas muscle, descending aorta, portal vein, and vena cava inferior. Circular regions of interest