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# Effect of automated tube voltage selection, integrated circuit detector and advanced iterative reconstruction on radiation dose and image quality of 3rd generation dual-source aortic CT angiography: An intra-individual comparison

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ABSTRACT

*Purpose:* To compare, on an intra-individual basis, the effect of automated tube voltage selection (ATVS), integrated circuit detector and advanced iterative reconstruction on radiation dose and image quality of aortic CTA studies using 2nd and 3rd generation dual-source CT (DSCT).

*Material and methods:* We retrospectively evaluated 32 patients who had undergone CTA of the entire aorta with both 2nd generation DSCT at 120 kV using filtered back projection (FBP) (protocol 1) and 3rd generation DSCT using ATVS, an integrated circuit detector and advanced iterative reconstruction (protocol 2). Contrast-to-noise ratio (CNR) was calculated. Image quality was subjectively evaluated using a five-point scale. Radiation dose parameters were recorded.

*Results:* All studies were considered of diagnostic image quality. CNR was significantly higher with protocol 2 ($15.0 \pm 5.2$ vs $11.0 \pm 4.2$; $p < .0001$). Subjective image quality analysis revealed no significant differences for evaluation of attenuation ($p = 0.08501$) but image noise was rated significantly lower with protocol 2 ($p = 0.0005$). Mean tube voltage and effective dose were $94.7 \pm 14.1$ kV and $6.7 \pm 3.9$ mSv with protocol 2; $120 \pm 0$ kV and $11.5 \pm 5.2$ mSv with protocol 1 ($p < 0.0001$, respectively).

*Conclusion:* Aortic CTA performed with 3rd generation DSCT, ATVS, integrated circuit detector, and advanced iterative reconstruction allow a substantial reduction of radiation exposure while improving image quality in comparison to 120 kV imaging with FBP.



## 1. Introduction

Patients with aortic disease commonly require life-long surveillance, including imaging, regardless of treatment approach [1]. CT angiography (CTA) is the preferred non-invasive imaging modality for both initial diagnosis and follow-up, due to its excellent sensitivity and specificity [2] and widespread availability. For patients undergoing endovascular or surgical aortic repair, follow-up is recommended at 1, 6, and 12 months, and then on a yearly basis [1]. Due to the need for repeated follow-up imaging, radiation dose reduction strategies are of special interest in this clinical

*Abbreviations:* CTA, CT angiography; DSCT, dual-source CT; ATVS, automated tube voltage selection; FBP, filtered back projection; BMI, body mass index; ROI, region on interest; HU, Hounsfield units; SD, standard deviation; SNR, signal-to-noise ratio; CNR, contrast-to-noise ratio; FOM, figure of merit; ED, effective dose; CTDI, CT dose index; DLP, dose-length product.

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population. Established radiation reduction techniques for CTA include decreasing the tube potential [3–6], high-pitch acquisition [3–5,7–9], and iterative reconstruction [6,10–13]. Altogether, the combination of such techniques has been shown to maintain or even improve image quality while reducing radiation dose, a benefit especially evident with algorithms allowing the selection of optimal tube potential based on anatomical characteristics of the patient's body habitus [14–17]. A recently introduced 3rd generation dual-source CT (DSCT) system provides further specialized developments including new X-ray tubes with increased power reserves, an optimized integrated circuit detector, and the routine implementation of advanced iterative reconstruction. All these features increase the potential for further lowering radiation exposure while maintaining or improving image quality [18–20].

The aim of this study was to assess the effect of automated tube voltage selection (ATVS), integrated circuit detector, and advanced iterative reconstruction on radiation dose and image quality of aortic CTA studies performed with a 3rd generation DSCT compared to the results of CTA studies previously performed in the same patients at a standard tube voltage of 120 kV.

## 2. Material and methods

### 2.1. Patient population

This retrospective study was approved by the local Institutional Review Board with a waiver of informed consent.

We identified 41 patients (29 men and 13 women) with aortic disease who had undergone CTA of the entire aorta performed with a 2nd generation DSCT system (SOMATOM Definition Flash, Siemens Healthcare, Forchheim, Germany) and a follow-up on a 3rd generation DSCT system (SOMATOM Force, Siemens Healthcare) between January 2011 and April 2015. Patients were excluded from the evaluation if a different pitch factor was used across scans (n = 9). CTA indications were post-operative follow-up of vascular surgery or endovascular aneurysm repair in patients with aortic aneurysm (n = 11) or reevaluation of aortic dissection (n = 21). Age and body mass index (BMI) were recorded for each patient.

### 2.2. CT acquisition parameters

The 3rd generation DSCT system was equipped with a fully integrated circuit detector system (Stellar Infinity, Siemens) and allowed for tube voltage selection ranging from 70 to 150 kV at 10 kV increments. 2nd generation DSCT CTA studies had been performed at a standard tube voltage of 120 kV [7]. ATVS was implemented on this system since our study, however was not yet available for clinical routine at the time of these examinations. The same holds true for the fully integrated circuit detector (Stellar, Siemens) which is by now also available for this system; however all examinations in this study had been performed before the detector upgrade.

A prospectively ECG-triggered acquisition protocol was used on both scanners and images were acquired at approximately 70% of the cardiac cycle depending on the heart rate. All studies were performed using automated attenuation-based tube current modulation (CARE Dose4D, Siemens).

For 2nd generation DSCT acquisition parameters were: 120 kV tube voltage, 400 mAs reference tube current, 2 × 64 × 0.6 mm detector collimation, gantry rotation 0.28 s, 512 × 512 pixel matrix size (examination protocol 1).

For 3rd generation DSCT studies, image acquisition was performed with ATVS (CAREkV, Siemens, reference tube voltage of 100 kV, reference tube current of 147 mAs for standard-pitch and 174 mAs for high-pitch CTA). Other acquisition parameters were: adaptive detector collimation varying from 96 to 192 in steps of 8 × 0.6 mm, gantry rotation 0.25 s, 512 × 512 pixel matrix size (examination protocol 2).

For both DSCT systems, the pitch was 3.2 for high-pitch and 0.6 for standard-pitch CTA.

The scan length ranged from the proximal portions of the supraaortic arteries to the iliac arteries.

Iodinated contrast agent (350 mgI/mL iohexol, Omnipaque, General Electric, Chalfont St. Giles, UK) was administered intravenously using a modified, previously proposed protocol for aortic CTA [21]. Flow rate was ranging from 2.5 to 5 mL/s in order to maintain an injection duration longer than 15 s and the contrast medium bolus was followed by a 50 mL saline chaser injected at the same flow rate.

For 2nd generation DSCT CTA, contrast medium volume was adapted to BMI (<20 kg/m$^2$, 90 mL; 20–25 kg/m$^2$, 100 mL; 26–30 kg/m$^2$, 110 mL; 31–35 kg/m$^2$, 120 mL; 36–40 kg/m$^2$, 130 mL; 41–45 kg/m$^2$, 140 mL; >45 kg/m$^2$, 150 mL).

For 3rd generation DSCT CTA, contrast medium volume was adapted to tube voltage (70 kV, 40 mL; 80 kV, 50 mL; 90 kV, 60 mL; 100 kV, 70 mL; 110 kV, 80 mL; ≥120 kV, 100 mL) due to more efficient X-ray attenuation of iodine at low-kV settings.

Scan initiation was determined using bolus tracking software (CARE Bolus, Siemens). A region of interest (ROI) was placed within the descending aorta at the level of the carina and the scan started automatically 4s after a threshold of 100 Hounsfield units (HU) was reached.

### 2.3. Image reconstruction

All 2nd generation DSCT studies were reconstructed with FBP and a medium sharp convolution kernel (B30f); the 3rd generation DSCT examinations with dedicated 3rd generation advanced modeled iterative reconstruction (ADMIRE, Siemens) with strength level of 3 using a medium sharp convolution kernel (Bv36) [22]. Section thickness was 1.5 mm with an increment of 1.0 mm.

### 2.4. Objective image quality analysis

For objective and subjective image analysis, dedicated post-processing and evaluation software (syngo.via VA30, Siemens) was used.

**Table 1**
Patient characteristics.

| | DSCT examination protocol 1 | | | DSCT examination protocol 2 | | | *p*-Value* |
|---|---|---|---|---|---|---|---|
| | Standard-pitch CTA | High-pitch CTA | Total | Standard-pitch CTA | High-pitch CTA | Total | |
| Age (years) | 59.8 ± 14.7 | 59.9 ± 13.7 | 59.9 ± 13.8 | 62.6 ± 14.1 | 60.7 ± 13.7 | 61.7 ± 14.3 | <0.0001 |
| BMI (kg/m$^2$) | 31.8 ± 5.6 | 27.5 ± 5.0 | 29.1 ± 5.6 | 31.3 ± 5.7 | 27.0 ± 3.9 | 29.1 ± 5.4 | 0.9593 |
| Tube voltage (kV) | 120.0 ± 0.0 | 120.0 ± 0.0 | 120 ± 0.0 | 90.7 ± 13.9 (70–120) | 96.0 ± 13.9 (80–120) | 94.7 ± 14.1 (70–120) | <0.0001 |
| Contrast medium (mL) | 126.4 ± 15.5 | 114.3 ± 30.3 | 122.8 ± 18.5 | 79.3 ± 23.2 | 75.6 ± 18.7 | 77.1 ± 20.5 | 0.0002 |

Mean values ± standard deviation, kV: kilovoltage, mSv: millisievert, DSCT: dual-source CT, CTA: CT angiography.
* *p*-Values relate to the comparison of the total number of CTA studies.