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Improved visual delineation of the intimal flap in Stanford type A and B dissections at 3rd generation dual-source high-pitch CT angiography

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Abstract
Objective Evaluation of the intimal flap visibility comparing 2nd and 3rd generation dual-source high-pitch CT.
Methods Twenty-five consecutive patients with aortic dissection underwent CT angiography on a second and third generation dual-source CT scanner using prospective ECG-gated high-pitch dual-source CT acquisition mode. Contrast material, saline flush and flow rate were kept equal for optimum comparability. The visibility of the intimal flap as well as the delineation of the different vascular structures was evaluated.
Results In 3rd generation dual-source high-pitch CT we could show a significant improvement of intimal flap visibility in aortic dissection. Especially, the far end of the dissection membrane could be better evaluated in 3rd generation high-pitch CT, reaching statistical significance ($P < 0.01$).
Conclusion 3rd Generation high-pitch CT angiography shows a better delineation of the aortic intimal flap in a small patient cohort, especially in the far ends of the dissection membrane. This might be due to higher tube power in this CT generation. However, to generalise these findings larger trials are needed.

Keywords CT angiography · Aorta · High-pitch CT · Dual-source CT

Introduction

Aortic dissection is a potentially fatal clinical emergency. Prevalence has been reported from 0.5 to 2.95 per 100,000/year with a mortality of 3.25–3.6 per 100,000/year [1]. Survival rates in the acute stage of Stanford type A and B

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dissection (DeBakey I–III) are very low with a fatality rate of up to 20 % before the hospital is reached [1–3]. Imaging in the emergency setting is vital for initial assessment [4]. Conservative therapy is the treatment of choice in the majority of Stanford type B dissections while Stanford type A dissections are referred for surgical or interventional treatment in nearly all cases [5]. Repeated imaging to exclude aortic rupture by assessment of the aortic dissection and the aortic diameter is an essential element when monitoring patients under conservative treatment [4, 6]. Available imaging modalities for follow-up of type B aortic dissections include computed tomography (CT), magnetic resonance imaging (MRI), ultrasound and conventional angiography [5]. Several technical advances have pre-dispositioned CT angiography amongst these. Current generation dual-source CT scanners are capable of pitch values above 3 [7], which makes full length aortic scanning in sub-second levels feasible [8–12]. The primary advantage of this technique is the ability to virtually freeze motion. Dual-source high-pitch acquisition is especially beneficial in the evaluation of the thoracic aorta where heart and aortic motion artefacts can mimic aortic dissection [10, 13]. As third generation dual-source CT scanners are now available, image acquisition in high-pitch mode has become increasingly widespread in clinical routine.

The objective of our study was therefore to evaluate the influence of a new CT scanner generation on the delineation of the aortic dissection membrane using 2nd and 3rd generation dual-source CT imaging for the follow-up of confirmed aortic dissection.

Materials and methods

Subjects

This study was performed using a single-centre, observer-blinded, retrospective design. The local ethics committee approved this study, and informed consent was waived because of the retrospective nature of the study. All primary patients who underwent clinically indicated CTA of the entire aorta for follow-up of aortic dissection from October 2013 to October 2014 were included in this study.

This patient cohort consisted of 25 individuals (Table 1). From these, 50 CT studies were included in this analysis. Each patient had received two scans: the first scan on a second generation dual-source CT (SOMATOM Definition Flash; Siemens Healthcare, Forchheim, Germany), and the second scan on a third generation dual-source CT (SOMATOM Force; Siemens Healthcare, Forchheim, Germany). The time period between both examinations was set by the referring clinician and ranged from 6 to 12 months.

Table 1 Study population and evaluation of examination parameters

Patients	25
Male/female	16/9
Age	62.1 (37–84)
BMI (kg/m^2)	24.2 ± 3.3 (19.3–27.9)

Table 2 Examination parameters

	Group 1	Group 2
CT mode	Dual-source	Dual-source
Machine	Definition flash	Definition force
Slice × collimation	2 × 128 × 0.6	2 × 192 × 0.6
Pitch	3.2	3.2
ROI	Desc. Aorta	Desc. Aorta
HU threshold	200.0	200.0
Reference kV/reference mAs per rotation	100/250	100/250
ECG gating	On	On
Delay	7.0 s	7.0 s
Dose management	Care kV	Care kV

For the analysis, two groups were defined depending on the CT scanner used (Table 2).

CT protocols

Group 1 underwent CTA on a 2nd generation dual-source CT device operated in prospective ECG-gated dual-source high-pitch mode (SOMATOM Definition Flash, Siemens Healthcare, Forchheim, Germany) with a pitch of 3.2, collimation of 2 × 128 × 0.6 mm using *z*-flying focal spot, and rotation time of 0.28 s.

Group 2 was examined on a 3rd generation dual-source CT device operated in prospective ECG-gated dual-source high-pitch mode (SOMATOM Force, Siemens Healthcare, Forchheim, Germany) with a pitch of 3.2, collimation of 2 × 192 × 0.6 mm using *z*-flying focal spot, and rotation time of 0.25 s.

All protocol parameters other than CT scanner model were kept constant between the two groups (Table 1). Automatic tube current modulation as well as automated tube potential selection was used in all groups (CareDose4D and CarekV, Siemens Healthcare, Forchheim, Germany). Image acquisition was performed in the craniocaudal direction in deep inspiratory breath-hold. The scan length included the entire chest, abdomen and pelvis in all cases (from superior thoracic aperture to the inguinal ligaments). All patients were examined for follow-up of their aortic dissection under conservative treatment.

Contrast medium volume was kept constant between both groups at 90 mL of iodinated contrast material (iodine concentration: 400 mg/mL, Imeron 400, Bracco Imaging, Konstanz, Germany) followed by a 50 mL saline chaser bolus. An 18–20 G intravenous access on the patient's forearm was used for contrast injection with a flow of 4 mL/s using a double-syringe power injector (Injektron CT2, Medtron, Saarbruecken, Germany). CTA was automatically triggered by the bolus-tracking technique; the ROI was placed in the descending thoracic aorta at the height of the pulmonary trunk and the trigger threshold was set at 200 HU. The start delay was set to 7 s in both groups.

Transverse images were reconstructed at 0.75 mm slice thickness with 0.5 mm increment, a matrix size of 512 × 512 and a CTA window (centre: 100 HU; width: 700 HU). Furthermore, for a quick overview, transverse 5.0 mm slices with 5.0 mm increments were reconstructed. For 3D evaluation, coronal and parasagittal reformations at 2 mm slice thickness with 2 mm increments were reconstructed. Group 1 images were reconstructed using a medium-soft convolution kernel in filtered back projection (B30f). Group 2 images were reconstructed using a medium-soft convolution kernel in filtered back projection technique (Bv 36) [14].

Image analysis

Objective image analysis

Measures of objective image quality were performed by a radiologist with 5 years of experience in CT angiography on a commercially available PACS workstation (Centricity 4.2, General Electric Healthcare, Munich, Germany). Several region-of-interest (ROI) measurements were drawn using a circle tool (ascending aorta, descending aorta, aorta at celiac trunk, femoral artery). Image noise was determined as the standard deviation of air measured presternally at the level of the ascending aorta. Based on these measurements, the signal-to-noise ratio (SNR) was determined according to the following equation: SNR = attenuation/image noise.

Subjective image analysis

Subjective image quality rating was conducted by two independent radiologists (with 4 and 5 years' experience in reading CTA examinations) in a blinded fashion. This rating followed a 5-point Likert-scale for each parameter (5 = excellent; 4 = good; 3 = moderate; 2 = fair; 1 = unacceptable). The parameter 'overall image quality' was used to grade the depiction of aortic pathologies (e.g. false/true lumen, thrombosis). For evaluation of the intimal flap, we evaluated, based on the quality of the images, the reader's ability to rule out type A and B dissections, to define the start- and end-point of each dissection, as well as to visually delineate the intimal flap at mid distance between these two points. The rating further included visualisation of the coronary ostia for analysis of movement artefacts (5 = no artefacts; 4 = minimal artefacts; 3 = moderate artefacts; 2 = extensive artefacts; 1 = severe artefacts).

Radiation exposure

CT dose index ($CTDI_{vol}$; in mGy) was recorded from the patient protocol, which is automatically generated at the end of each examination. All protocols were adjusted to similar kV/ref. mAs settings using automated dose control software (Table 1).

Statistical analysis

All statistical analyses were performed using dedicated software (Stata/IC 13.1, StataCorp LP, Texas, USA). Continuous variables are expressed as median and range; categorical variables are expressed as frequencies or percentages. The Wilcoxon signed rank test was used to compare image noise, attenuation and dose values. A $P < 0.05$ was defined as statistically significant. A Cohen's kappa analysis was performed to determine inter-observer agreement for subjective image quality scoring.

Results

All CT examinations were of diagnostic image quality; no examinations had to be excluded from analysis. Contrast enhancement was rated as sufficient in all patients.

Objective image quality

Median SNR of the aorta at the level of the coeliac trunk was 36.6 for group 1 and 41.2 for group 2 ($P = 0.03$) (Table 4). Image noise in group 1 was significantly higher than in group 2 ($P = 0.002$).

Subjective image quality

Visual comparison of the intimal flap revealed a significant difference in the visualisation of the proximal as well as the distal intimal flap region (Table 3). In the central region of the aortic dissection membrane image quality was comparable between both groups ($P = 0.2$). Differentiation between type A and type B dissections was possible in all patients. For each patient, Stanford classification of the dissection was equal in both examinations. There were no motion artefacts present (Table 3).

Table 3 Image quality rating between the different groups

	Group 1	Group 2	*P* value
Delineation of the proximal intimal flap	3.7	4.5	<0.01
Delineation of the middle intimal flap	4.6	4.5	0.2
Delineation of the distal intimal flap	3.4	4.7	<0.01
Overall quality	4.5	4.8	>0.05
Elimination of movement artefacts	5.0	4.9	>0.05
Coronary ostia	4.5	4.6	>0.05
Classification "Type A or Type B Dissection" possible	25 of 25	25 of 25	

Table 4 Radiation dose and objective image analysis

Scanning range	71.4 (41.6–83.6) cm	72.3 (40.3–86.2) cm	>0.1
Scanning duration	1.8 (0.9–2.1) s	1.7 (0.9–2.0) s	0.5
CTDIvol	4.85 (2.2–8.1) mGy	3.81 (1.9–7.5) mGy	0.001
Image noise	12.3 (7.8–26) HU	9.8 (6.3–28.1) HU	0.002
SNR	36.6 (21.3–52.4)	41.2 (19.4–63.8)	<0.05

Inter-observer agreement was good with a Cohen's κ value of 0.77.

Radiation exposure

Parameters of radiation exposure only reached statistically significant differences for $CTDI_{volume}$ (Table 4). Group 2 had a median $CTDI_{volume}$ of 3.81 mGy compared to 4.85 mGy in Group 1. Imaging time and imaging length were comparable in both groups and did not reach statistical significance (Table 4).

Discussion

In our study, we showed a significant improvement of image quality in evaluation of the proximal and distal ends of the intimal flap using 3rd generation dual-source high-pitch CT.

This improvement of intimal flap visualisation is directly related to the reader's ability to judge progression of the intimal tear. This was the case both proximally and distally to the extent present in the previous CT study. This is one of the most important features in follow-up imaging of aortic dissection. We found improvements in image quality that were especially noticeable on the distal end of the dissection membrane (Figs. 1, 2, 3). As image reconstruction did not differ, we think that the main driver in this setting is the higher tube output in the new 3rd generation CT scanner compared to the 2nd generation CT scanner [15].

In clinical routine a verification of the intimal flap along the patient *z*-axis is one of the main questions of the referring clinician. To date, it is not described how detailed the

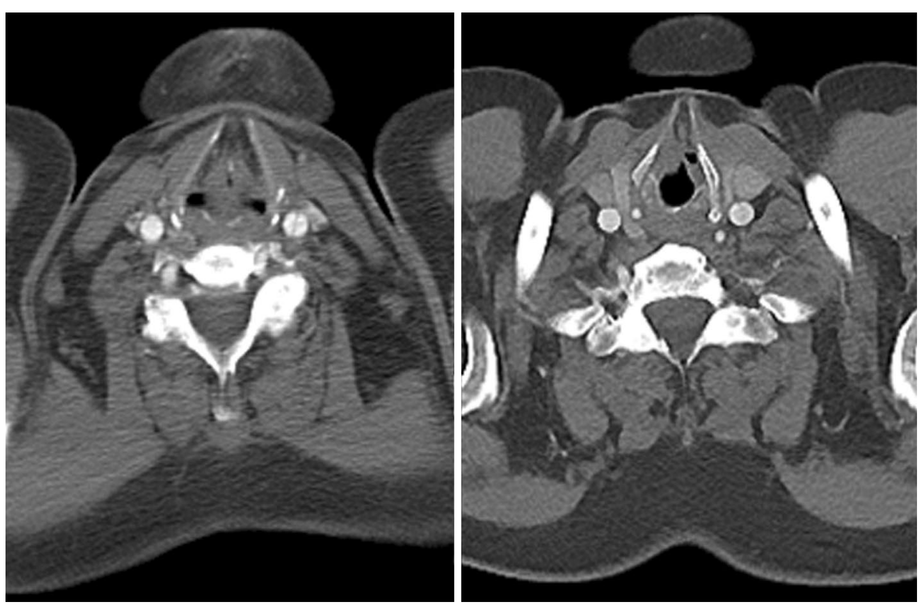

Fig. 1 Left: Group 2 (SOMATOM Force); Right: Group 1 (Definition Flash). The dissection membrane in the left carotid artery has not been described in the first radiologic report (*right hand side*), because it was not visible. Imaging on 3rd generation dual-source CT has clearly visualised the dissection membrane (*left hand side*)

Fig. 2 *Left* group 1 (Definition Flash); *Right* group 2 (SOMATOM Force). Dissection membrane in the abdominal part of the Aorta. No visible differences between both examination protocols

Fig. 3 Dissection membrane (Stanford A-Dissection) in 3rd generation dual-source CT (Force)

intimal flap description is at need and if a small dissection, in the end, really changes the therapy. Larger trials are needed to focus on these questions.

Radiation dose was found to be roughly constant, while automated tube current modulation and automated tube potential selection (Care kV, Siemens Healthcare, Forchheim, Germany) were enabled in both groups (image quality parameters in Table 1). The dose modulation software selects the tube potential as well as the tube current according to the patients' habitus. Because the examined patients were the same in both groups, we consider this assessment of radiation dose valid, as far as can be evaluated with a population group of this size. Third generation computed tomography is a relatively new technology that has been available since late 2013. Therefore, only a few comparable clinical observations for coronary heart CT exist to date [16, 17]. Gordic et al. reported a radiation dose of 3.2 mSV for a thoraco-abdominal examination, with a coronary CT angiography protocol at a pitch of 3.2 imaged with 120 kVp using automated tube potential selection [16]. Compared to second generation dual-source CT, Meyer et al. found a significant reduction of radiation exposure as well as contrast material using 70 keV as well as dual-source high-pitch CT for the imaging of cardiac vessels [17]. In this study by Meyer et al. the radiation dose reduction is likely to be a result of the adjustment of the tube potential to 70 keV.

In our data, contrast enhancement was adequate in all cases within our study. Both groups reached a median vascular enhancement above 300 HU. This is in line with enhancement values of vessel enhancement reaching 200 HU or higher reported in the literature [18–20].

In this study, a threshold of 200 HU was used, since a lower threshold will result in higher delay-times. There are two common strategies for the timing of contrast bolus: either the test-bolus or the bolus-tracking method is used [21, 22]. In previous evaluations, a contrast material enhancement threshold of 50 HU was determined to be adequate for diagnostic image quality [18]. However, as ongoing developments have led to increased imaging speeds [18], there has been a trend considering the higher attenuation thresholds necessary for adequate vessel enhancement in CT angiography. The bolus-tracking technique, however, remains a gold standard for imaging of the aorta from the results of this study, since it is both easy to use and does not require a second injection of contrast material.

Limitations

We are aware of several limitations of this study. First, we used a qualitative image scoring system to evaluate the aortic intimal flap. This evaluation is subject to potential observer bias. To balance this potential bias, we conducted the evaluation with two experienced radiologists. As a further measure, both readers were blinded to the date and relevant details of the examinations. The resulting interobserver agreement was good, suggesting that observer bias was low.

Another limitation is the retrospective approach; however, this observational study might be a first step for further evaluations.

Finally, due to the fast table movement, the CT tube operates at a tube current close to its absolute capacity. This is the case, especially in 2nd generation dual-source high-pitch imaging [15]. In 3rd generation dual-source high-pitch CT, both X-ray tubes are capable of generating a peak tube current of 1300 mA. According to protocol output, however, the capacity of tube output was not reached in either examination.

Conclusion

Third generation high-pitch dual-source CT significantly improves delineation of proximal and distal ends of the intimal flap in aortic dissections. However, to really verify if a better delineation leads to a change in clinical treatment, larger trials are needed.

Compliance with ethical standards

Conflict of interest No funding was received for this work. The authors declare no potential conflict of interest.

Ethical standards The local ethics committee approved this study, and informed consent was waived because of the retrospective nature of the study. All procedures performed were in accordance with the ethical standards of the institutional research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards.

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