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Time-resolved CT angiography in aortic dissection

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ABSTRACT

Objectives: We performed this study to assess feasibility and additional diagnostic value of time-resolved CT angiography of the entire aorta in patients with aortic dissection.
Materials and methods: 14 consecutive patients with known or suspected aortic dissection (aged 60 ± 9 years) referred for aortic CT angiography were scanned on a dual-source CT scanner (Somatom Definition Flash; Siemens, Forchheim, Germany) using a shuttle mode for multiphasic image acquisition (range 48 cm, time resolution 6 s, 6 phases, 100 kV, 110 mAs/rot). Effective radiation doses were calculated from recorded dose length products. For all phases, CT densities were measured in the aortic lumen and renal parenchyma. From the multiphasic data, 3 phases corresponding to a triphasic standard CT protocol, served as a reference and were compared against findings from the time-resolved datasets.
Results: Mean effective radiation dose was 27.7 ± 3.5 mSv. CT density of the true lumen peaked at 355 ± 53 HU. Compared to the simulated triphasic protocol, time-resolved CT angiography added diagnostic information regarding a number of important findings: the enhancement delay between true and false lumen ($n = 14$); the degree of membrane oscillation ($n = 14$); the perfusion delay in arteries originating from the false lumen ($n = 9$). Other additional information included true lumen collapse ($n = 4$), quantitative assessment of renal perfusion asymmetry ($n = 2$), and dynamic occlusion of aortic branches ($n = 2$). In 3/14 patients (21%), these additional findings of the multiphasic protocol altered patient management.
Conclusions: Multiphasic, time-resolved CT angiography covering the entire aorta is feasible at a reasonable effective radiation dose and adds significant diagnostic information with therapeutic consequences in patients with aortic dissection.

1. Introduction

Aortic dissection (AD) is a life-threatening condition, in which an intimal tear in the aortic wall forms a dissection membrane creating a true and a false intramural lumen. Males are affected more commonly than females. The annual incidence of AD has been estimated to equal 3–4/100.000 and incidence strongly correlates with age [1–4]. Depending on its location, AD may have potentially fatal complications such as malperfusion of brain, coronary arteries, spinal cord, kidneys, bowel and lower extremities as well as aortic rupture, shock or uncontrollable hypertension [1,5]. Mortality is significantly higher for type A dissections than for type B dissections [1,5].

The type and extent of aortic dissection largely determines the outcome. Therefore, dedicated imaging is crucial in AD for the evaluation of the entire aorta, as well as potential involvement of thoracic and abdominal branches of the aorta [6,7]. The obstruction of branch vessels may be static or dynamic: In the former, the intimal flap enters and occludes the branch vessel origin, while in dynamic obstruction, the intimal flap spares the branch vessel origin, but prolapses and occludes it temporarily during the heart cycle [6].

Dynamic obstructions are frequently missed when using standard imaging techniques such as conventional computed tomography angiography (CTA), since they are unable to adequately assess dynamic changes in AD, such as blood flow patterns and oscillation of the dissection membrane.

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Table 1
CT examination protocol.

Phases	6
Time resolution	6 s
Tube voltage	100 kV
Tube current	110 mAs/rot
Dose length product	1628 ± 204 mGy × cm
Effective radiation dose	27.7 ± 3.5 mSv
Range	48 cm
Contrast volume	60 mL
Flow rate	5.0 mL/s
Maximum aortic contrast	355.1 ± 52.8 HU
Background noise	10.3 ± 2.3 HU
Computed tomography dose index	32.4 ± 2.8 mGy
Signal-to-noise-ratio	38.8 ± 11.9
Dissection completely shown	*n* = 6, yes
	n = 8, no
Complications	None

MR angiography (MRA) [8] and contrast-enhanced ultrasound (CEUS) [9] have been used for time-resolved imaging in aortic dissection. These modalities, however, have several disadvantages compared to CTA. In most settings, MR angiography is not as readily available as CTA, particularly in emergency indications. Also, CT offers higher spatial resolution than MR angiography and image acquisition is faster [10]. CEUS offers the potential of dynamic imaging, but is highly dependent on the physician's experience and may be time-consuming, being therefore also not optimal for an emergency setting.

Recent advances in CT technology enable for time-resolved CT imaging by using a shuttle mode, that is, a bidirectional table movement during image acquisition, providing dynamic image acquisitions. The feasibility of time-resolved computed tomography angiography (TR-CTA) of the aorta has previously been demonstrated using a limited field of view of 27 cm [11]. We performed this study to assess the feasibility of TR-CTA with a range of 48 cm covering both thoracic and abdominal aorta in patients with AD. In this pilot study we further aimed to assess the potential additional diagnostic value of TR-CTA in patients with AD as compared to a simulated triphasic standard CTA protocol.

2. Materials and methods

2.1. Patient population

Between April 2009 and April 2010, we included 14 consecutive patients who were referred for CTA of the thoracic and abdominal aorta, either for follow-up of aortic dissection ($n = 13$) or with clinical suspicion of acute aortic dissection ($n = 1$). The local ethics committee approved the study. Written informed consent was obtained from all patients prior to participating in this study. Patients with a body mass index (BMI) above 30 kg/m^2 were excluded from this study.

2.2. CT Examination protocol

The TR-CTA scans were performed on a Dual-Source, multidetector row CT scanner (Somatom Definition Flash; Siemens Medical Solutions, Forchheim, Germany). This scanner contains two X-ray tubes with two corresponding 64-channel detectors and a Z-flying spot, generating 128 slices per gantry rotation with a collimation of 0.6 mm per detector. Furthermore, this scanner offers the possibility of time-resolved imaging for a field of view of up to 48 cm by using a shuttle mode, that is, a bidirectional table movement during image acquisition.

All patients underwent a time-resolved CT angiography of the thoracic and abdominal aorta (scan range 48 cm, see Table 1). We used an intermittent image acquisition meaning that only craniocaudal table movements were scanned. Each cycle of craniocaudal and caudocranial table movements had a duration of 6 s, resulting in a temporal resolution of 6 s. The first scan started 14 s after the injection of the contrast agent. We performed 6 phases of imaging, resulting in a total scanning time of 36 s. Scans were acquired with free shallow breathing.

To limit radiation exposure, tube voltage and tube current were set to 100 kV and 110 mAs/rot, respectively. 60 mL of the contrast medium containing 370 mg/mL iodine (Iopromid, Ultravist 370®, Bayer Healthcare) were applied at a flow rate of 5.0 mL/s, followed by a saline bolus of 100 mL (flow rate, 5.0 mL/s). 1.5 mm slices were reconstructed from the primary data sets resulting in a voxel size of 0.5 mm × 0.5 mm × 1.5 mm.

2.3. Calculation of effective radiation dose

The computed tomography dose indices (CTDIs) and dose length products (DLPs) were recorded from patient protocols. To calculate the resulting effective radiation dose from the DLP, a conversion factor of 0.017 mSv/mGy was used [12].

2.4. Image analysis

For evaluation of the imaging data a dedicated 3D workstation was employed (Siemens Leonardo, Siemens Medical Solutions, Erlangen, Germany) and reading was performed in consensus by 2 radiologists with 5 and 12 years of experience in CT angiography. The TR-CTA was displayed in a movie mode, with a dynamic visualization of both the axial slices and volume rendering technique reconstructions. The movies, consisting of 6 dynamic phases each, could be stopped and advanced manually at any time. From the 6 phases of the TR-CTA dataset, 3 phases corresponding to a standard triphasic protocol (non-enhanced, arterial and venous phase) were chosen to serve as a reference.

2.5. Calculation of signal-to-noise-ratio

Mean Hounsfield unit values of the aorta were determined in all phases with a standardized region of interest (ROI) sized 1 cm^2 within both the true and the false lumen. Background noise was determined by measuring the standard deviation of the CT density of a standardized ROI sized 1 cm^2 placed in the air just above the body surface. SNR was calculated using the formula: Maximum enhancement of true lumen (HU)/Background noise (HU).

2.6. Comparison of diagnostic confidence in determination of dissection characteristics

Various diagnostic findings were determined for both the triphasic and the time-resolved protocol. These included:

- origin of renal arteries, mesenteric arteries and celiac trunk from the true or false lumen,
- involvement of aortic root and supraaortic vessels,
- presence of an endoleak in patients with endovascular stent grafts,
- time difference in enhancement between true and false lumen.

For each of these diagnostic decisions, diagnostic confidence was rated separately for the dynamic and triphasic datasets on a 3-point scale (1 = uncertain, 2 = moderately confident, 3 = fully confident). Additionally, overall image quality was rated on a 5-point scale ranging from 0 = insufficient to 4 = excellent.