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Image quality and contrast agent exposure in cardiac computed tomography angiography prior to transcatheter aortic valve implantation procedures using different acquisition protocols

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A R T I C L E I N F O

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A B S T R A C T

Background: ECG-gated cardiac computed tomography angiography (CCTA) has found widespread use for prosthesis sizing before transcatheter aortic valve implantation (TAVI). However, still little data exists on the optimal scan-strategy in such patients. We hypothesized that prospectively triggered CCTA can enable the visualization of aortic valve structures and peripheral arteries with lower radiation and contrast agent exposure in patients considered for TAVI compared to retrospectively gated protocols.
Methods: All studies were performed using a 256 multi-detector single source CT (iCT Philips, Best, Netherlands). With the prospective protocol the whole volume from the heart to the iliofemoral arteries scanned using prospective triggering. With the retrospective protocol a first retrospectively gated scan was performed for the heart and the iliofemoral part was subsequently scanned using a second non-triggered scan. Image quality was assessed semi-quantitatively and signal-to-noise- (SNR) and contrast-to-noise-ratios (CNR) were obtained for all scans.
Results: Prospective CCTA was performed in 74 and in 34 patients, respectively using non-tailored and BMI adapted scans, whereas retrospective CCTA was performed in 57 patients. Prospective scans required lower contrast agent administration compared to retrospective scans (71 ± 8 mL versus 91 ± 15 mL, $p < 0.01$) and resulted in lower radiation exposure (26 ± 7mSv for retrospective versus 15 ± 3mSv for non-tailored prospective versus 8 ± 4mSv for BMI-adapted prospective scans, $p < 0.01$). Visual image quality was better for the evaluation of aortic valve structures and similar for the assessment of iliofemoral anatomy with prospective versus retrospective scans. In addition, contrast density, SNR and CNR were higher in the ascending aorta with prospective versus retrospective CCTA (434 ± 98HU versus 349 ± 112HU; 35 ± 14 versus 24 ± 9 and 31 ± 11 versus 16 ± 7, $p < 0.001$ for all). Subsection analysis by heart rate groups demonstrated that both image quality and CNR were significantly higher in patients with prospective versus retrospective CCTA, irrespective of the heart rate during image acquisition.
Conclusion: Prospectively triggered CCTA allows for improved visualization of aortic valve structures and peripheral arteries in patients scheduled for TAVI with simultaneously reduced contrast agent dose and radiation exposure. Therefore, this acquisition mode seems to be the preferred for the evaluation of patients considered for TAVI.

1. Introduction

Transcatheter aortic valve implantation (TAVI) has evolved as an important alternative treatment option for high and possibly moderate risk patients with severe aortic stenosis. [1–3] In contrast to surgery however, where sizing is performed under direct visualization of the aortic root, pre-procedural imaging using either echocardiography or computed tomography angiography is essential prior to TAVI to minimize periprocedural complications. [4–6] Thus, prosthesis sizing can prevent complications such as occlusion of the coronary ostia, annular

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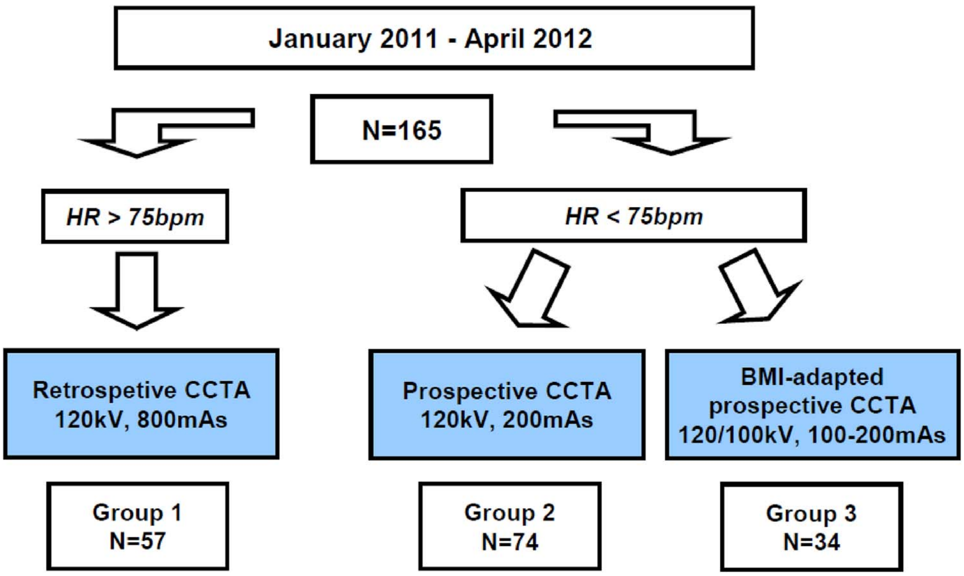

Fig. 1. Flow-chart including 57 patients who underwent retrospective, 74 patients who underwent non-tailored prospective and 34 patients who underwent BMI-adapted prospective CCTA acquisitions and were systematically analyzed in terms of radiation exposure and image quality.

rupture, device dislodgement and paravalvular regurgitation. [7,8]

The aortic annulus is anatomically defined as a virtual ring with 3 anatomical anchors at the nadir of each aortic leaflet. Its complex 3D-geometry and its crown-like and simultaneously elliptical shape may therefore limit the accuracy of 2D-measures by transthoracic or trans-esophageal echocardiography. [9] Technical developments with cardiac computed tomography angiography (CCTA) on the other hand, have recently enabled the accurate assessment of aortic valve structures in patients considered for TAVI. [6] However, contrast agent dose and radiation exposure raise concerns for the use of CCTA in patients considered for TAVI, especially in those with reduced renal function, which is quite common in such patients.

In the present study, we therefore sought to investigate the influence of different CCTA scanning protocols in terms of contrast agent and radiation exposure and on the resultant image quality for the assessment of aortic valve structures. We compared subjective image quality, signal-to-noise (SNR), contrast-to-noise ratios (CNR), and contrast agent and radiation exposure with 256-slice CCTA using retrospectively gated versus prospectively triggered protocols.

2. Methods

2.1. Study population

The study group included 165 consecutive patients with symptomatic severe aortic stenosis between January 2011 and September 2012 who underwent CCTA prior to TAVI. They were systematically analyzed in terms of contrast agent, radiation exposure and resultant image quality. Patient body weight and height were recorded at the time of the CCTA. All procedures complied with the Declaration of Helsinki, were approved by our local ethic committee and all patients gave written informed consent.

2.2. 256-slice CT scans

CCTA scans were performed using a 256-slice Brilliance iCT scanner (Philips Healthcare) that features a gantry rotation time of 270 ms, resulting in a temporal resolution of 36–135 ms, depending on the heart rate of the patient and the performance of multi-segment reconstruction algorithms, and an isotropic sub-millimeter spatial resolution.

For CCTA a bolus of the contrast agent (Ultravist 370, Bayer Schering Pharma) was injected intravenously using an antecubital I.V. line. The contrast agent was injected at a flow of 4 mL/sec followed by a saline flush (50 mL at a flow of 5 mL/s). The scan started automatically using a bolus tracking with a region of interest placed in the descending aorta and a threshold of 110 Hounsfield Units (HU). The entire volume of the heart was acquired during one breath-hold in 4–7 s with simultaneous ECG recording. The detector collimation was $2 \times 128 \times 0.625$ mm, with 256 overlapping slices of 0.625 mm thickness and dynamic z-focal spot. No premedication with ß-blockers or nitrates was given due to severe aortic stenosis in all patients.

Study design acquisition. A flow chart illustrating the 3 different acquisition protocols used in our study is provided in Fig. 1.

Patients with a heart rate ≥ 75bpm before CCTA (Group 1, n = 57), underwent a retrospectively EGC-gated helical scan of the heart (tube voltage 120 kV, tube current of 800mAs), which was then followed, after a time delay of 8–10 s, by an untriggered scan of the lower abdominal aorta and the peripheral iliofemoral vessels (tube voltage 120 kV, tube current of 200mAs).

Patients with heart rate < 75bpm before CCTA were randomly assigned to non-tailored prospectively triggered CCTA (Group 2, n = 74) (tube voltage 120 kV, tube current of 800mAs) versus BMI-adapted prospectively triggered CCTA (Group 3, n = 34) (tube voltage 100 kV, tube current of 100–200mAs, depending on patient habitus and using the iDose technique for image reconstruction. [10] In both Group 2 and 3 a single prospectively triggered CCTA scan was used for full coverage from the heart down to the peripheral iliofemoral vessels.

With prospective scans, diastolic images (75% of the cardiac cycle) were used for assessment of aortic valve structures. With retrospective scans both systolic (40% of the cardiac cycle) and diastolic images (75% of the cardiac cycle) were used, and the images with the higher quality for the evaluation of the aortic valve were considered. Representative images of a patient who underwent a retrospectively EGC-gated helical scan (a-d) and of a patient who underwent prospectively triggered CCTA (e-h) can be appreciated in Fig. 2.

2.3. Estimation of the radiation exposure

The dose-length product (DLP) was obtained from the patient dose report. The effective dose was calculated for all scans, based on DLP and an average organ weighting factor for the chest as the investigated anatomic region ($k = 0.014$ mSv × (mGy × cm)$^{-1}$) averaged between male and female models. [11] Hereby, it should be noted that a uniform conversion coefficient for all images is not entirely accurate as it does not account for all different conditions and factors in each individual examination.