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Research paper

Very low intravenous contrast volume protocol for computed tomography angiography providing comprehensive cardiac and vascular assessment prior to transcatheter aortic valve replacement in patients with chronic kidney disease

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ABSTRACT

Background: Transcatheter aortic valve replacement (TAVR) is a lifesaving procedure for many patients high risk for surgical aortic valve replacement. The prevalence of chronic kidney disease (CKD) is high in this population, and thus a very low contrast volume (VLCV) computed tomography angiography (CTA) protocol providing comprehensive cardiac and vascular imaging would be valuable.
Methods: 52 patients with severe, symptomatic aortic valve disease, undergoing pre-TAVR CTA assessment from 2013–4 at Columbia University Medical Center were studied, including all 26 patients with CKD (eGFR<30 mL/min) who underwent a novel VLCV protocol (20 mL of iohexol at 2.5 mL/s), and 26 standard-contrast-volume (SCV) protocol patients. Using a 320-slice volumetric scanner, the protocol included ECG-gated volume scanning of the aortic root followed by medium-pitch helical vascular scanning through the femoral arteries. Two experienced cardiologists performed aortic annulus and root measurements. Vascular image quality was assessed by two radiologists using a 4-point scale.
Results: VLCV patients had mean (±SD) age 86 ± 6.5, BMI 23.9 ± 3.4 kg/m^2 with 54% men; SCV patients age 83 ± 8.8, BMI 28.7 ± 5.3 kg/m^2, 65% men. There was excellent intra- and inter-observer agreement for annular and root measurements, and excellent agreement with 3D-transesophageal echocardiographic measurements. Both radiologists found diagnostic-quality vascular imaging in 96% of VLCV and 100% of SCV cases, with excellent inter-observer agreement.
Conclusions: This study is the first of its kind to report the feasibility and reproducibility of measurements for a VLCV protocol for comprehensive pre-TAVR CTA. There was excellent agreement of cardiac measurements and almost all studies were diagnostic quality for vascular access assessment.

1. Introduction

Transcatheter aortic valve replacement (TAVR) has become a standard treatment option for patients with severe, symptomatic aortic stenosis considered high-risk for surgical AVR.[1,2]. One of the many significant comorbidities in this patient population is chronic kidney disease (CKD), which negatively affects outcomes and also poses challenges for computed tomography angiography (CTA) evaluation, used to assess aortic root anatomy and arterial

Abbreviations: BMI, body mass index; CKD, chronic kidney disease; CTA, computed tomography angiography; GFR, glomerular filtration rate; HU, Hounsfield Units; IV, intravenous; PVL, paravalvular leak; SCV, standard contrast volume; TAVR, transcatheter aortic valve replacement; VLCV, very low contrast volume.

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access.[3,4]. A low contrast volume CTA protocol providing accurate cardiac-gated imaging and complete vascular access assessment while minimizing iodinated contrast volume would be of great clinical benefit. No previous reports of CTA for pre-TAVR assessment in patients with CKD include both a complete, noninvasive cardiac and vascular assessment with the same low volume contrast bolus and quantitatively assess both cardiac and vascular measurements with assessment of measurement reproducibility in comparison to a standard volume protocol.[5–8]

2. Technical methods

2.1. Patient selection

52 patients with severe, symptomatic aortic valvular disease being evaluated for TAVR from March 25, 2013 through November 5, 2014 at Columbia University Medical Center were retrospectively evaluated. 26 consecutive patients with severe (class 4 or higher CKD, body-mass index <40 kg/m^2) underwent a novel low contrast volume comprehensive CTA for pre-TAVR assessment; 26 without CKD underwent our standard contrast volume protocol. The study was approved by the institutional review board.

2.2. Imaging procedure

Using a 320-slice volumetric scanner (Aquilion One, Toshiba America Medical Systems, Otawara, Japan), the very low contrast volume (VLCV) protocol included retrospective, single-heartbeat-duration ECG-gated volume scanning of the aortic root immediately followed by medium-pitch-helical (pitch factor 1.03) vascular scanning from aortic arch to femoral arteries using a single contrast bolus. Intravenous injection of 20 mL of iohexol 350 mg iodine/mL (Omnipaque, GE Healthcare, Princeton, NJ) was followed by 30 mL saline flush, both at 2.5 mL/s. During an inspiratory breath-hold, single-volume root acquisition was performed with prospective electrocardiographic triggering and 240–320 × 0.5 mm collimation, followed by vascular scanning with 100 × 0.5 mm collimation. The scanner required a 5.5–6.3 s delay between volumetric and helical scans. For control cases, 60 mL of contrast was injected followed by 30 mL saline flush, both at 3.5 mL/s. Tube current and potential were selected by either the supervising physician or automated software with the goal of maximizing image quality and reducing radiation exposure. Tube potential was equal for aortic root and vascular scans. Real-time bolus tracking in the descending thoracic aorta was used for scan timing. Breath-hold and scan were initiated at 80 and 130 Hounsfield Unit (HU) thresholds, respectively, for VLCV, and 130 and 180HU for standard contrast volume (SCV), with manual triggering if necessary.

2.3. Annular/aortic and vascular imaging

For annular imaging, iterative image reconstruction used slice-thickness of 0.5 mm and 5% phase intervals (maximum 20 phases) while vascular images were reconstructed at 1 mm. Reconstructed datasets were analyzed using 3mensio valve software (v5.1, Pie Medical Imaging, Netherlands) and Vitrea software (v6.5.3, Vital Images, Minnetonka, MN) for cardiac[9] and vascular analysis, respectively. Best systolic and diastolic phases were selected. Two blinded, experienced cardiologists (TCP, OKK) performed annular (area, perimeter, maximum/orthogonal minimum diameter), and root (annulus-to-coronary ostia distance, sinuses of Valsalva width/height, sinotubular junction diameters) measurements. One cardiologist (TCP) repeated measurements >2 weeks apart in randomly-selected case order. Two experienced, blinded radiologists (AR, GDNP) independently graded iliofemoral vascular image quality on a semiquantitative 4-point ordinal scale (1 = nondiagnostic; 2 = diagnostic but limited; 3 = good, mild limitations; 4 = excellent). Average luminal CT number was measured at annular and common femoral artery level for each patient. For 32 patients subsequently undergoing TAVR with intraprocedural 3-dimensional transesophageal echocardiography (3D-TEE), comparison of annular area and perimeter measurements were made to a previously-validated 3D-TEE approach.[10]

2.4. Statistical analysis

Inter-observer and intra-observer agreement for aortic annular and aortic anatomic measurements were determined using intraclass correlation coefficients (ICCs). Vascular image quality score agreement was determined using weighted kappa. Clinical endpoints/adverse events were compared between groups using the log-rank test. Two-tailed *t*-tests evaluated differences between groups. ($P < 0.05$ significant). Analyses were performed using Stata (v12.1/13.1, StataCorp, College Station, Texas) and MedCalc (v15.4, Software Ostend, Belgium).

3. Technical results

3.1. Aortic root measurements

Table 1 details baseline patient and imaging characteristics. Fig. 1 shows examples of two excellent-image-quality VLCV cases.

Table 1
Baseline characteristics and CT scan details.

	VLCV Group (n = 26)	SCV Group (n = 26)	p Value
Age, years	85.7 ± 6.5	83.2 ± 8.8	0.26
Male, %	53.9 (14)	65.4 (17)	0.40
BMI, kg/m^2	23.9 ± 3.4	28.7 ± 5.3	0.0003
Coronary artery disease, %	61.5	56.0	0.69
Atrial fibrillation, %	38.5	36.0	0.86
STS score, %	9.8 ± 4.1	9.1 ± 5.4	0.58
LVEF, %	55.5 ± 12.7	55.7 ± 16.1	0.96
AVA, cm^2	0.65 ± 0.17	0.78 ± 0.14	0.009
AVA index, cm^2/m^2	0.38 ± 0.6	0.42 ± 0.78	0.04
Tube potential, 80/100/120 kV	(5)/(19)/(2)	(0)/(17)/(9)	0.008
Mean tube current, aortic root study, mA	385	426	0.24
Mean CT number, aortic annulus, HU	288	450	0.0001
Mean tube potential, vascular imaging, kV	98	107	0.002
Mean tube current, vascular imaging, mA	314	304	0.72
Mean CT number, common femoral artery, HU	200	420	0.0001

Abbreviations: BMI = body mass index. STS = Society of Thoracic Surgeons. LVEF = left ventricular ejection fraction. AVA = aortic valve area. kV = kilovolts. mA = milliampere.