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Diagnostic Efficacy and Safety of Low-Contrast-Dose Dual-Energy CT in Patients With Renal Impairment Undergoing Transcatheter Aortic Valve Replacement

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Objective: This study aimed to evaluate the diagnostic efficacy and safety of low-contrast-dose, dual-source dual-energy CT before transcatheter aortic valve replacement (TAVR) in patients with compromised renal function.
Materials and Methods: A total of 54 consecutive patients (female:male, 26:38; 81.9 ± 7.3 years) with reduced renal function underwent pre-TAVR dual-energy CT with a 30-mL contrast agent between June 2022 and March 2023. Monochromatic (40- and 50-keV) and conventional (120-kVp) images were reconstructed and analyzed. The subjective quality score, vascular attenuation, contrast-to-noise ratio (CNR), and signal-to-noise ratio (SNR) were compared among the imaging techniques using the Friedman test and post-hoc analysis. Interobserver reliability for aortic annular measurement was assessed using the intraclass correlation coefficient (ICC) and Bland-Altman analysis. The procedural outcomes and incidence of post-contrast acute kidney injury (AKI) were assessed.
Results: Monochromatic images achieved diagnostic quality in all patients. The 50-keV images achieved superior vascular attenuation and CNR (P < 0.001 in all) while maintaining a similar SNR compared to conventional CT. For aortic annular measurement, the 50-keV images showed higher interobserver reliability compared to conventional CT: ICC, 0.98 vs. 0.90 for area and 0.97 vs. 0.95 for perimeter; 95% limits of agreement width, 0.63 cm^2 vs. 0.92 cm^2 for area and 5.78 mm vs. 8.50 mm for perimeter. The size of the implanted device matched CT-measured values in all patients, achieving a procedural success rate of 92.6%. No patient experienced a serum creatinine increase of ≥ 1.5 times baseline in the 48–72 hours following CT. However, one patient had a procedural delay due to gradual renal function deterioration.
Conclusion: Low-contrast-dose imaging with 50-keV reconstruction enables precise pre-TAVR evaluation with improved image quality and minimal risk of post-contrast AKI. This approach may be an effective and safe option for pre-TAVR evaluation in patients with compromised renal function.
Keywords: Aortic valve stenosis; Transcatheter aortic valve replacement; Computed tomography angiography; Contrast media; Monochromatic

INTRODUCTION

Preprocedural CT before transcatheter aortic valve replacement (TAVR) is essential for determining the treatment strategy [1]. The number of patients undergoing TAVR is increasing annually [2]. However, the older, high-

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risk population undergoing TAVR often presents with chronic kidney disease, and the using substantial quantities of iodinated contrast agents for CT angiography in these patients can increase their susceptibility to acute kidney injury (AKI), which is associated with poor outcomes [3].

Some researchers have explored the feasibility of using non-contrast CT for pre-TAVR evaluation [4,5]. In severe aortic stenosis, aortic valve calcification can be used as a reference point to assess the aortic annulus. However, the accuracy of non-contrast CT scans may be compromised, especially in cases with minimal aortic valve calcification, making it challenging to delineate the aortic valve leaflets. Therefore, it is essential to conduct preprocedural assessments using minimal contrast agents while ensuring diagnostic image quality.

Dual-energy CT (DECT) offers a range of virtual monochromatic images [6], allowing the selection of optimal monochromatic energies to enhance the contrast-to-noise ratio (CNR) or minimize noise or beam-hardening artifacts [7]. A previous study demonstrated its effectiveness in reducing beam-hardening artifacts and improving the CNR and overall image quality compared with conventional CT [8]. Notably, virtual monochromatic images acquired at low-keV levels offer superior contrast enhancement with reduced contrast agent doses [6]. Therefore, this technique is beneficial for patients requiring contrast reduction.

Previous studies attempted pre-TAVR evaluation using DECT [9-11]. However, these studies had limitations such as the restricted use of the dual-energy mode in aortoiliac scans [9], the use of standard contrast doses in individuals with normal renal function [10], and the sole use of dual-layer spectral-detector CT [11]. Consequently, studies on pre-TAVR evaluations using low-contrast-dose agents and the dual-energy method with the currently widely adopted third-generation dual-source CT are limited. This study aimed to assess the diagnostic efficacy and safety of pre-TAVR evaluation using a low-contrast-dose, dual-source, dual-energy CT in patients with compromised renal function.

MATERIALS AND METHODS

Study Participants and Clinical Data

This retrospective, single-center study was approved by the Institutional Review Board (IRB No. KC23RISI0573). The requirement for written informed consent was waived.

The study population is shown in Figure 1. The inclusion

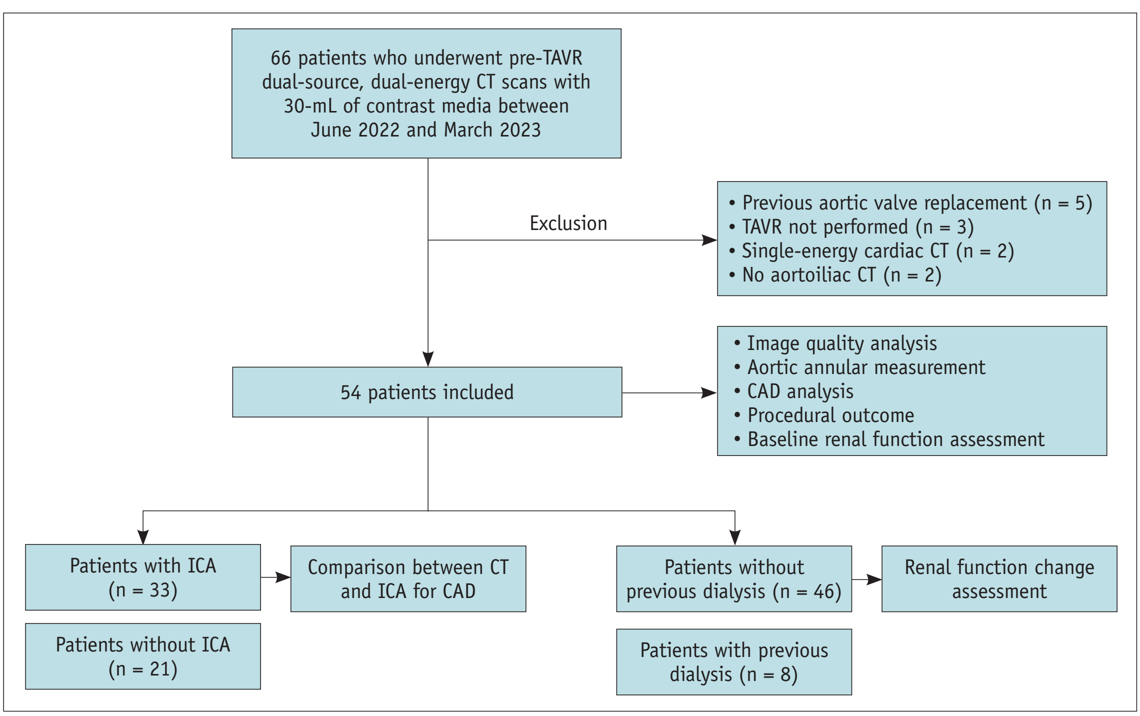

Fig. 1. Study participants. Of 66 patients who underwent pre-TAVR CT with 30 mL contrast media between June 2022 and March 2023, we excluded those with a history of aortic valve replacement, those who did not undergo the TAVR procedure, those who had single-energy cardiac CT scans, and those without delayed aortoiliac CT scans. As a result, our analysis included 54 patients. The number of patients included in each analysis is described. TAVR = transcatheter aortic valve replacement, CAD = coronary artery disease, ICA = invasive coronary angiography

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criteria were individuals who underwent pre-TAVR CT using a 30 mL contrast agent at our institution between June 2022 and March 2023. Exclusion criteria included the following: patients with previous aortic valve replacement (n = 5), those in whom TAVR was not performed (n = 3), use of single-energy cardiac CT (n = 2), and unavailable aortoiliac CT (n = 2).

Data on age, sex, height, weight, body mass index (BMI), serum creatinine level, and estimated glomerular filtration rate (eGFR) were collected. Serum creatinine level and eGFR were measured before and after the CT scan. For the latter, the highest serum creatinine level and its corresponding eGFR values within 48–72 hours following the CT scan were recorded.

CT Acquisition Protocol

All examinations were performed using a third-generation dual-source CT scanner (SOMATOM Force; Siemens Healthineers, Forchheim, Germany). Cardiac CT was performed using a retrospective electrocardiographically gated helical acquisition in all patients. For CT angiography, a bolus of 15 mL iomeprol (350 mgI/mL; Iomeron, Bracco; Milan, Italy) was injected at a flow rate of 3 mL/s, followed by 50 mL of 30% blended iomeprol with saline and 20 mL of saline at 3 mL/s. For each patient, scan delay times between the start of contrast agent injection and CT angiography were determined using the bolus-tracking technique, with placement of the region of interest (ROI) in the ascending aorta. Scans were performed in dual-energy mode with 90/Sn150 kVp tube voltage, adaptive tube current, 250 msec rotation time, 192 x 0.6 mm collimation, and adaptive pitch. Real-time automatic mAs modulation

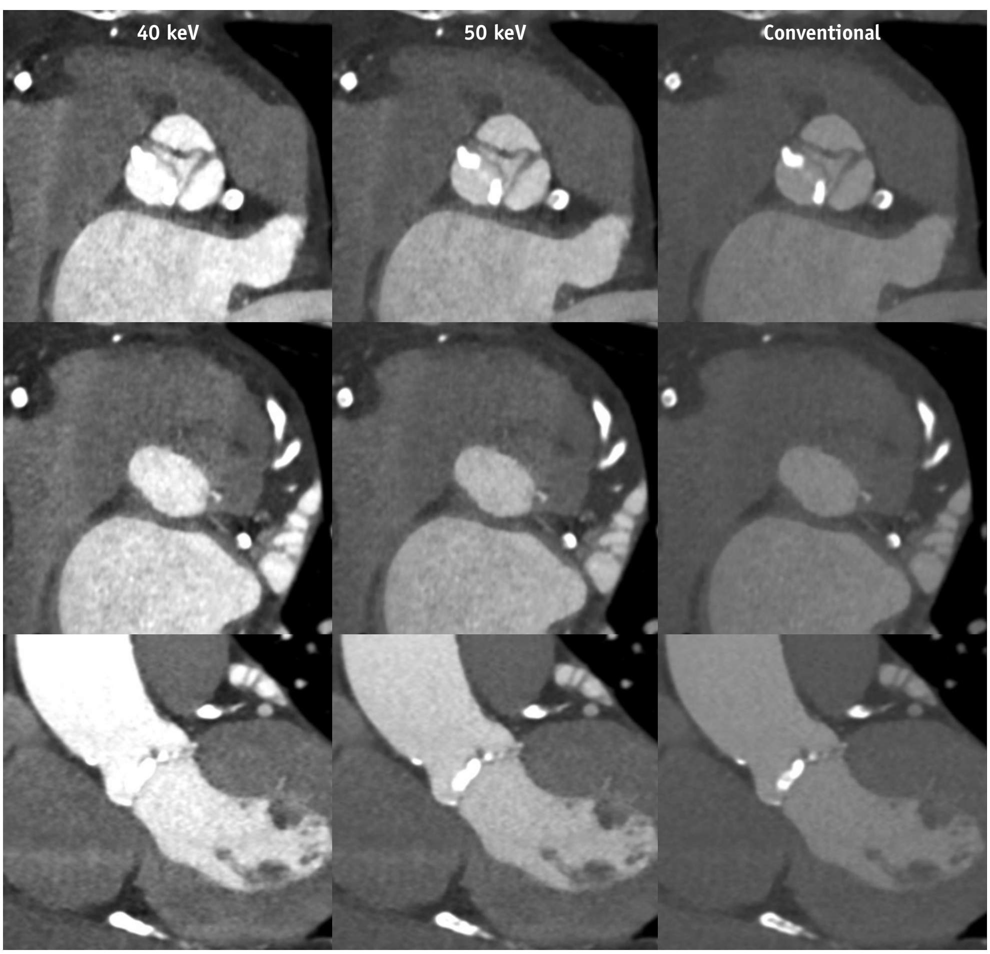

Fig. 2. Examples of 40-keV, 50-keV, and conventional CT images, presented in the axial double-oblique view for the measurement of the aortic valve opening area (top) and annulus (middle), and the coronal oblique view (bottom). The monochromatic images exhibit superior vascular opacification and contrast-to-noise ratio compared to conventional images. However, at 40-keV, increased noise and blooming artifacts are observed due to aortic valve calcium. The 50-keV images demonstrate adequate contrast enhancement with reduced levels of noise and artifacts.

software (CARE Dose 4D; Siemens Healthineers; Forchheim, Germany) was used to reduce radiation exposure. Beta-blockers were not administered before scanning. The mean dose length product was 641.7 (standard deviation [SD] 256.9) mGy·cm.

CT Reconstruction

Axial images were reconstructed at the end-systolic or mid-diastolic phase using a 0.75-mm section thickness, 0.5-mm increment interval, and soft tissue kernel Bv36 with Advanced Modeled Iterative Reconstruction (ADMIRE) strength 2. All datasets were post-processed using a dedicated dual-energy 3D multimodality workstation (Syngo.via, version VB40A, Siemens Healthcare). Three image series were reconstructed for evaluation in this study (Fig. 2). First, virtual monoenergetic images with photon energies of 40-keV and 50-keV were reconstructed. Images at higher energy levels were not reconstructed because of suboptimal iodine attenuation during image review. Additionally, weighted averages of 120-kVp images were reconstructed. These were calculated through linear blending of the original low- and high-energy images with a 0.6 weighting ratio to form an image set with CT numbers close to those from the 120-kVp single-energy acquisition [12,13]. The weighted average of 120-kVp images was considered conventional CT.

Image Quality Assessment

Two independent cardiac radiologists (S.C. and S.K.B.) assessed the subjective quality of the CT images. CT images were evaluated in a randomized order in a blinded manner during three sessions with one-week washout periods between sessions. During each session, a single image set for each patient was randomly chosen from the conventional, 40-keV, and 50-keV images. The readers were allowed to adjust the window settings individually to enhance visualization. Subjective image quality was scored visually according to the following four-point scale (quality score): 1, non-diagnostic image quality with insufficient vessel opacification or severe artifacts/noise; 2, interpretable image quality with moderate artifacts/noise; 3, good image quality with adequate opacification and mild artifacts/noise; and 4, excellent image quality with good opacification and minimal artifacts/noise (Supplementary Fig. 1).

To assess the objective image quality, three sets of images were displayed simultaneously, side by side, and a cardiac radiologist (SC) positioned the ROI within the left ventricular outflow tract (LVOT), ascending aorta, and descending thoracic aorta. To ensure consistency, both the size and placement of the ROIs remained constant throughout each CT dataset, which was achieved using a copy-and-paste function. Attenuation and SD measurements were performed on the vascular segments. Additionally, an extra ROI measurement was conducted within an adjacent intercostal muscle, with the resulting SD of the specific measurement accounting for image noise. The CNR and signal-to-noise ratio (SNR) were calculated using the formula [14]; CNR = vessel enhancement in Hounsfield units (HU) minus adjacent muscle tissue enhancement divided by the adjacent muscle tissue enhancement SD; SNR = vessel enhancement in HU divided by vessel enhancement SD.

Aortic Annulus Measurement

For measurement of the aortic annulus, all images were transferred to an offline workstation (Aquarius iNtuition V4.4.13; TeraRecon, San Francisco, CA, USA) for analysis. The size of the aortic annulus was measured by two independent cardiac radiologists (S.C. and J.I.J.). Randomization was not employed in this session, and the readers were not blinded to the imaging methods used. Each reader performed double-oblique reformation on every dataset while remaining unaware of the results achieved by the other reader. Double-oblique reformations oriented parallel to the virtual basal ring of the ventriculo-aortic junction were reconstructed to measure the area and perimeter of the aortic annulus.

Coronary Artery Stenosis Evaluation

Coronary artery stenosis was evaluated with a combined review of all image sets; the image quality was assessed as either acceptable or non-acceptable for coronary evaluation by a cardiac radiologist (S.C.), who also determined the presence of significant stenosis (diameter stenosis ≥ 50%). In patients who underwent invasive coronary angiography (ICA), the accuracy of CT in detecting significant coronary artery stenosis was assessed using the ICA as the reference standard.

Clinical Outcomes

TAVR was performed using measurements from clinical practice. Cardiac radiologists selected the most appropriate images after reviewing all image sets. In the clinical setting, radiologists at our institution commonly select 50-keV images, although the specific images utilized for the measurements are not recorded. Procedural success was defined as the absence of periprocedural mortality, correct positioning of a single prosthetic valve at an ideal

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anatomical location, and good prosthesis performance (no prosthesis-patient mismatch, mean aortic valve gradient < 20 mm Hg or peak velocity < 3 m/s, and absence of significant regurgitation) [15].

We assessed pre- and post-CT renal function to determine renal function deterioration and the requirement for dialysis after CT in patients who had not undergone dialysis. Post-contrast AKI was defined as an increase in serum creatinine of ≥ 1.5 times baseline in the 48–72 hours following contrast media injection [16]. We also assessed whether renal function deterioration due to CT angiography caused any delay or interruption in the TAVR procedure.

Statistical Analysis

Continuous variables are presented as mean ± SD or median (interquartile range [IQR]). To compare the subjective and objective image quality among the imaging methods, the Friedman rank-sum test was applied, followed by post-hoc analysis using the Conover test with Bonferroni correction [17,18]. Interobserver reliability in measuring the size of the aortic annulus within each image set was assessed using the intraclass correlation coefficient (ICC) with a two-way random model under absolute agreement and Bland-Altman analysis. Pearson's correlation coefficients were calculated. The Wilcoxon signed-rank test and paired *t*-test were used to compare the baseline and follow-up serum creatinine levels and eGFR values, respectively. Statistical analyses were conducted using R software (version 4.0.5; R Foundation for Statistical Computing, https://www.r-project.org). Statistical significance was defined as $P < 0.05$.

RESULTS

Characteristics of Study Participants

Table 1 presents the characteristics of the study participants. This study included 54 patients with an average age of 81.9 ± 7.3 years, of whom 48.1% were female. The mean BMI was 24.6 ± 3.9 kg/m^2. The average heart rate was 70.1 ± 13.1 bpm. Six of the 54 patients (11.1%) had atrial fibrillation and two (3.7%) showed premature ventricular contractions on electrocardiography. The aortic stenosis etiology was degenerative in all included patients. Before CT, the baseline serum creatinine was 2.1 ± 2.2 mg/dL and eGFR was 40.4 ± 19.1 mL/min/1.73 m^2. Of the 54 patients, eight were undergoing dialysis before the CT scan. A balloon-expandable device was used in 40.7% of cases, while 59.3% received a self-expanding device.

Table 1. Demographics and clinical data of patients

Parameter	Value (n = 54)
Age, yrs	81.9 ± 7.3
Sex, female:male	26 (48.1):28 (51.9)
Height, cm	157.5 ± 10.0
Weight, kg	61.1 ± 11.4
BMI, kg/m^2	24.6 ± 3.9
Heart rate, bpm	70.1 ± 13.1
Arrhythmia	
No	46 (85.2)
Atrial fibrillation	6 (11.1)
Premature ventricular contractions	2 (3.7)
Type of aortic stenosis	
Degenerative	54 (100.0)
Bicuspid or rheumatic	0
Pre-CT Serum creatinine, mg/dL	2.1 ± 2.2
Pre-CT eGFR, mL/min/1.73 m^2	40.4 ± 19.1
Below 15	7 (13.0)
Between 15 and 29	5 (9.3)
Between 30 and 59	38 (70.4)
Between 60 and 89	4 (7.4)
Dialysis before CT	8 (14.8)
Device	
Balloon-expandable	22 (40.7)
Self-expanding	32 (59.3)

Values are mean ± standard deviation or number (percentage). BMI = body mass index, eGFR = estimated glomerular filtration rate

Image Quality Assessment

Table 2 presents the subjective image quality scores of the monochromatic and conventional CT images provided by the two readers. Both readers found significant differences in the image quality scores among the image sets (P = 0.005 for reader 1 and < 0.001 for reader 2). Among the three image sets, the 50-keV images exhibited the highest median score, with a median of 4 (IQR, 3–4) for reader 1 and a median of 3.5 (IQR, 3–4) for reader 2. Both readers assigned a median score of 3 to the conventional and 40-keV images. In the pairwise comparison, both readers showed a significant difference between the 50-keV and conventional images (P = 0.023 and < 0.001 for readers 1 and 2, respectively).

Table 3 presents a comparison of the vascular attenuation, CNR, and SNR between monochromatic and conventional CT. Vascular attenuation measurements obtained from the LVOT, ascending aorta, and descending thoracic aorta revealed that vascular attenuation was highest at 40-keV, followed by 50-keV and then conventional images, with statistically significant differences (P < 0.001 in all segments). In

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Table 2. Subjective image quality score on monochromatic and conventional CT

Image quality score	Reader 1			Reader 2		
	40-keV	50-keV	Conventional	40-keV	50-keV	Conventional
Median (Q1–Q3)	3 (3–4)	4 (3–4)	3 (3–4)	3 (3–4)	3.5 (3–4)	3 (2–4)
1: non-diagnostic	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	3 (5.6)
2: interpretable	11 (20.4)	7 (13.0)	10 (18.5)	8 (14.8)	7 (13.0)	12 (22.2)
3: good	17 (31.5)	18 (33.3)	18 (33.3)	23 (42.6)	20 (37.0)	13 (24.1)
4: excellent	26 (48.1)	29 (53.7)	26 (48.1)	23 (42.6)	27 (50.0)	26 (48.1)
P-value (overall)		0.005			< 0.001	
P-value in pairwise comparison*						
40-keV vs. 50-keV		0.006			0.286	
40-keV vs. conventional		> 0.999			0.061	
50-keV vs. conventional		0.023			< 0.001	

Values are median (Q1–Q3) or number (percentage).
*Adjusted *P*-value with Bonferroni correction

Table 3. Vascular attenuation, SNR, and CNR in monochromatic and conventional CT

Location and parameter	40-keV	50-keV	Conventional	*P*-value (overall)	*P*-value in pairwise comparison*		
					40-keV vs. 50-keV	40-keV vs. conventional	50-keV vs. conventional
LVOT							
Vascular attenuation, HU	544.5 (421.8–693.0)	364.0 (285.8–467.8)	199.0 (159.5–256.0)	< 0.001	< 0.001	< 0.001	< 0.001
CNR	19.1 (15.2–29.7)	17.2 (12.9–24.2)	13.0 (9.0–17.4)	< 0.001	< 0.001	< 0.001	< 0.001
SNR	10.0 (7.4–11.7)	10.0 (7.5–12.0)	10.0 (7.7–12.5)	0.018	0.445	0.013	0.445
Ascending aorta							
Vascular attenuation, HU	669.0 (510.0–814.0)	449.0 (344.3–545.5)	240 (193.5–298.5)	< 0.001	< 0.001	< 0.001	< 0.001
CNR	24.3 (17.7–33.4)	21.1 (15.3–30.2)	15.6 (10.7–21.7)	< 0.001	< 0.001	< 0.001	< 0.001
SNR	15.0 (12.1–18.5)	15.6 (12.3–18.6)	15.9 (12.3–18.8)	0.029	0.107	0.037	> 0.999
Descending thoracic aorta							
Vascular attenuation, HU	664.5 (522.8–82.0)	449.0 (353.8–55.0)	241.0 (195.0–29.0)	< 0.001	< 0.001	< 0.001	< 0.001
CNR	25.8 (17.2–37.5)	22.6 (15.0–32.2)	15.15 (10.5–21.8)	< 0.001	< 0.001	< 0.001	< 0.001
SNR	12.6 (10.3–16.5)	12.95 (10.1–16.8)	12.85 (10.4–16.4)	0.004	0.008	0.010	> 0.999

Values are median (Q1–Q3).
*Adjusted *P*-value with Bonferroni correction.
SNR = signal-to-noise ratio, CNR = contrast-to-noise ratio, LVOT = left ventricular outflow tract, HU = Hounsfield units

pairwise comparisons, both 40- and 50-keV images showed significantly higher vascular attenuation than conventional images ($P < 0.001$ in all segments). CNR followed a similar pattern, with the highest values at 40-keV, followed by 50-keV and conventional images (Supplementary Fig. 2); these differences were statistically significant ($P < 0.001$ in all segments). In pairwise comparisons, both 40- and 50-keV images showed significantly higher CNR than conventional images ($P < 0.001$ in all segments). The SNR values exhibited minor variations between the groups, with slightly lower SNR values in the 40-keV images than in the other image sets (Supplementary Fig. 3). In pairwise comparisons, significant differences were found between the 40-keV and conventional CT images in all vascular segments (P = 0.013, 0.037, and 0.010 in the LVOT, ascending aorta, and descending thoracic aorta, respectively). However, there were no significant differences in the SNR between the 50-keV and conventional CT images (P = 0.445 in the LVOT and P > 0.999 in other segments).

Aortic Annulus Measurement

DECT with a low-contrast media protocol showed excellent interobserver reliability for all image sets (Table 4; ICCs > 0.85). Notably, the 50-keV images showed the highest ICC values in both measurements, with ICCs of 0.98 and 0.97 for area and perimeter, respectively.

For the aortic annular area measurements, the 50-keV images exhibited the closest agreement between the two readers (Supplementary Fig. 4). In Bland-Altman analysis, the lowest mean bias was observed at 40-keV (0.04 cm^2, 95% limits of agreement (LoA): -0.55 cm^2, 0.63 cm^2 [width 1.18 cm^2]). Notably, 50-keV images showed the narrowest 95% LoA, with a mean bias of 0.06 cm^2 (95% LoA: -0.25 cm^2, 0.38 cm^2 [width 0.63 cm^2]). In contrast, conventional images displayed the highest mean bias of 0.08 cm^2 (95% LoA: -0.38 cm^2, 0.54 cm^2 [width 0.92 cm^2]).

In measuring the aortic annular perimeter, the 50-keV images consistently demonstrated the closest agreement between the two readers (Supplementary Fig. 5). In Bland-Altman analysis, the lowest mean bias was found at 40-keV (0.47 mm, 95% LoA: -4.08 mm, 5.02 mm [width 9.1 mm]). The 50-keV images displayed the narrowest 95% LoA, with a mean bias of 0.55 mm (95% LoA: -2.34 mm, 3.44 mm [width 5.78 mm]), while conventional images exhibited a mean bias of 0.9 mm (95% LoA: -3.35 mm, 5.15 mm [width 8.50 mm]).

Coronary Artery Stenosis Evaluation

The majority of the cases, except for two, had acceptable quality for coronary artery assessment. The limitations in evaluating the coronary arteries in these two cases were due to motion artifacts and extensive coronary calcification. Among the 33 patients who underwent ICA, six CCTA cases were false positives for significant stenosis. Five of these cases involved an overestimation of stenosis due to calcification, and one case was attributed to motion artifacts in the right coronary artery.

Procedure Outcome and Renal Function Analysis

The sizes of the devices implanted in all patients corresponded to the CT-measured values. Follow-up echocardiography did not reveal evidence of a prosthesis-patient mismatch, without a significant increase in pressure gradient or peak velocity. However, three patients exhibited moderate paravalvular leak. The patients had severe aortic valve calcification, sub-annular calcification, or both. No intraprocedural deaths occurred, and two cases of cardiovascular mortality (one heart failure and one thrombotic microangiopathy) were noted within one month after TAVR, one of which included three patients with moderate paravalvular leak. After excluding these four cases, the procedural success rate was 92.6% (50/54).

For the 46 patients without pre-CT dialysis, the serum creatinine level was 1.4 ± 0.5 mg/dL before CT and 1.3 ± 0.6 mg/dL after CT (P < 0.001). The eGFR changed from a baseline of 45.3 ± 15.5 mL/minute/1.73 m^2 to 52.7 ± 19.3 mL/minute/1.73 m^2 after CT (P < 0.001) (Supplementary Fig. 6). None of the patients exhibited an increase in serum creatinine of ≥ 1.5 times baseline within 48–72 hours, indicative of post-contrast AKI. There was no delay in TAVR after CT in most patients. However, one patient with very low baseline renal function who received additional contrast agents had a delay in the TAVR procedure. This delay was attributed to a gradual increase in serum creatinine levels, rising from a baseline of 4.09 mg/dL to 5.53 mg/dL four days after the CT scan, leading to the initiation of continuous renal replacement therapy. Details of the procedural status and renal function before and after CT for each patient are presented in Supplementary Table 1.

Table 4. Interobserver reproducibility and agreement for the aortic annular measurement

Measurement	Intraclass correlation coefficient (95% confidence interval)			Mean difference (95% limits of agreement)		
	40-keV	50-keV	Conventional	40-keV	50-keV	Conventional
Area	0.93 (0.89, 0.96)	0.98 (0.96, 0.99)	0.90 (0.92, 0.97)	0.04 cm^2 (−0.55 cm^2, 0.63 cm^2),	0.06 cm^2 (−0.25 cm^2, 0.38 cm^2),	0.08 cm^2 (−0.38 cm^2, 0.54 cm^2),
Perimeter	0.94 (0.93, 0.96)	0.97 (0.96, 0.98)	0.95 (0.90, 0.97)	0.47 mm (−4.08 mm, 5.02 mm)	0.55 mm (−2.34 mm, 3.44 mm)	0.9 mm (−3.35 mm, 5.15 mm)

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DISCUSSION

This study provides real-world evidence that low-contrast-dose imaging with monochromatic reconstruction conducted on a third-generation dual-source, dual-energy CT enables sufficient pre-TAVR evaluation in patients with impaired renal function. The 50-keV images provided the highest image quality scores, along with superior vascular attenuation and CNR, while maintaining an SNR similar to that of conventional CT scans. For the aortic annular area and perimeter measurements, the 50-keV images showed the highest interobserver reproducibility, along with the narrowest LoA among all image sets. The aortic annular measurements on CT matched the device size used in all patients and led to a high procedural success rate. Although the diverse medical conditions among patients present a challenge in determining the specific impact of CT contrast agent use, both serum creatinine levels and eGFR remained stable after CT. A procedural delay in TAVR due to renal dysfunction was observed in only one patient in our study population.

Recently, there has been a growing assertion that adequate preventive measures are necessary to reduce AKI when considering TAVR in patients with chronic kidney disease to improve survival [19,20]. The key approach for preventing AKI is optimal hydration and reduction in the amount of contrast agent [21]. Reducing the amount of contrast agent required for the TAVR procedure can be challenging; however, decreasing the volume of contrast agent used for preprocedural CT evaluation can offer a relatively straightforward and consistent approach, irrespective of the patient's condition. In this regard, minimizing the volume of the contrast agent used for CT is highly important.

Diagnostic image quality was achieved using monochromatic imaging in all patients, although some patients with motion artifacts or heavy calcifications had lower scores. The 50-keV images obtained the highest image quality scores for both readers. This can be attributed to the comprehensive assessment of image quality considering vascular opacification, noise, and artifacts. Conventional images displayed inadequate opacification. The 40-keV images showed good opacification but had the disadvantage of pronounced noise and beam-hardening artifacts, as previously reported [22,23]. Therefore, it is possible that 50-keV images, which offer a balanced enhancement of opacification and image clarity, received a slightly higher score, as suggested by prior researchers [24].

The CNR was highest at 40-keV and lowest in the conventional images, with a statistically significant difference. These findings are consistent with the results of previous studies [10,11,25]. However, the distribution of the CNR was most diverse at 40-keV and was relatively uniform in conventional images. For the SNR, lower values were observed at 40-keV than other image sets. This result deviates from a previous study stating that 40-keV exhibited higher CNR and SNR than conventional images on a dual-layer spectral-detector CT [11]. This may be attributed to the reduction in noise in virtual monochromatic images from dual-layer spectral CT [26].

Prior research has demonstrated the feasibility of low-contrast 40-keV imaging with a dual-layer spectral-detector CT for pre-TAVR evaluation [11]. Our study further analyzed the interobserver reliability of aortic annular measurements across 40-keV, 50-keV, and conventional images. Our analysis revealed that 50-keV images attained the highest ICC and narrowest LoA, suggesting superior reliability between readers. This improvement may be attributed to the high noise levels at 40-keV and the suboptimal vascular opacification in conventional images, which could lead to a greater reliance on subjective judgment during annulus delineation. Consequently, 50-keV strikes a balance by providing adequate contrast for diagnosis while mitigating some of the issues associated with noise and beam-hardening artifacts at 40-keV, making it the most reproducible option.

A major drawback of dual-source dual-energy CT in cardiac imaging is its reduced temporal resolution [27]. In our study, we found that pre-TAVR evaluation using monochromatic images was possible. However, patients with high heart rates were more likely to experience motion artifacts. This poses challenges not only in assessing the aortic valve but also in evaluating coronary artery stenosis. Therefore, additional research is necessary to investigate methods that can reduce the amount of contrast agents while preserving temporal resolution.

Post-contrast AKI refers to a sudden decline in renal function that manifests within 48–72 hours after the intravenous administration of iodinated contrast medium [28]. In our study, the serum creatinine and eGFR values remained stable within 48–72 hours after the CT scan. Nevertheless, one patient with very low baseline renal function who received additional contrast agents experienced gradual renal function decline, leading to a delay in the TAVR procedure. The incidence of post-contrast AKI is higher in patients with preexisting renal dysfunction [29,30]. Renal function deterioration appears to be closely related to the general medical condition and underlying renal function of the patient, whereas additional contrast use acts as an exacerbating factor [31]. Although we have made significant reductions in contrast agent usage during CT scans, concerns persist regarding the potential impairment of renal function owing to the use of additional contrast agents in various procedures. Therefore, careful consideration is required when making decisions regarding the use of contrast agents, and continuous research is essential to further reduce contrast doses.

Our study has several limitations. First, this was a retrospective study conducted with a relatively small sample size at a single institution. Second, owing to ethical considerations in this study targeting patients with compromised renal function, a standard contrast dose was not administered. Instead, all participants received a minimal contrast dose, precluding comparison between the two groups. Despite the reduced volume of the contrast agent, all monochromatic images showed diagnostic image quality for preprocedural evaluation. Finally, we consistently administered 30 mL of contrast agent; however, the iodine load may vary among patients based on their body size. Although it would be ideal to determine the optimal iodine load by assessing the individual contrast kinetics for each patient, there is a paradox in using iodine contrast agents to determine contrast kinetics. Therefore, we reduced the dose to less than half the standard dose, which may have limitations in individuals with a high BMI. Future prospective studies with larger patient cohorts are necessary to further reduce the use of contrast agents in pre-TAVR evaluation.

In conclusion, low-contrast-dose imaging with dual-source, dual-energy CT allows accurate pre-TAVR evaluation while reducing the risk of post-contrast AKI. The 50-keV images enhance image quality and interobserver reliability compared with conventional CT, which can be beneficial for patients with compromised renal function.

Supplement

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Availability of Data and Material

The datasets generated or analyzed during the study are available from the corresponding author on reasonable request.

Conflicts of Interest

Kyunghwa Han, who holds the respective position of Statistical Consultant of the *Korean Journal of Radiology*, was not involved in the editorial evaluation or decision to publish this article. The remaining author has declared no conflicts of interest.

Author Contributions

Conceptualization: Jung Im Jung. Data curation: Suyon Chang. Formal analysis: Suyon Chang, Kyongmin Sarah Beck, Jung Im Jung, Kyunghwa Han. Funding acquisition: Suyon Chang. Investigation: Suyon Chang, Kyongmin Sarah Beck, Jung Im Jung. Methodology: Suyon Chang, Jung Im Jung, Yaeni Kim. Project administration: Jung Im Jung. Resources: Jung Im Jung, Kiyuk Chang. Supervision: Jung Im Jung. Validation: Suyon Chang, Kyongmin Sarah Beck, Jung Im Jung, Kyunghwa Han. Visualization: Suyon Chang. Writing—original draft: Suyon Chang. Writing—review & editing: all authors.

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