

Impact of Computed Tomography–Derived Body Composition on Mortality and Conduction Disturbances After Transcatheter Aortic Valve Implantation: A Sex-Specific Analysis

ABSTRACT

Background: Transcatheter aortic valve implantation (TAVI) is increasingly performed for severe aortic stenosis with improving procedural success rates; however, post-procedural complications remain a significant clinical challenge. Growing evidence suggests that sarcopenia may adversely affect morbidity and mortality in this patient population.

Methods: This retrospective, single-center cohort study included 171 patients undergoing elective TAVI (January 2018–February 2024). Muscle area (MA), visceral, subcutaneous (SATA), and total adipose tissue area (TATA) were measured at the L3 vertebral level from pre-procedural computed tomography angiography (CTA). Primary endpoints were all-cause and cardiac mortality; secondary endpoints were permanent cardiac conduction defect, permanent pacemaker implantation (PPI), and hospital stay.

Results: The cohort comprised 95 women (55.5%) and 76 men (44.5%), median age 78.9 years, society of thoracic surgeons score 6.30 (IQR = 4.37–9.33). Over 21.8 ± 17.9 months, 43 patients (25.1%) died, including 12 cardiac deaths (7.0%). Lower MA and MA/body mass index (BMI) ratio were independently associated with cardiac mortality in men (adjusted odds ratio [OR] = 0.935, $P = .016$ and OR = 0.983, $P = .042$). Permanent cardiac conduction defect occurred in 44 patients (27.7%); lower SATA and TATA were independent predictors in women (OR = 0.990, $P = .031$ and OR = 0.994, $P = .024$). Permanent pacemaker implantation was required in 30 patients (18.6%); adipose tissue parameters were associated with PPI in women on univariate analysis but did not retain significance after multiple adjustment.

Conclusion: Pre-procedural CTA-derived body composition assessment may contribute to the prediction of mortality and morbidity in TAVI patients without additional cost or radiation exposure. The association of lower MA with cardiac mortality in men, and of reduced adipose tissue with conduction disturbances in women, suggests that sex-specific body composition parameters may provide prognostic value beyond conventional risk scores.

Keywords: Body composition, muscle, sex characteristics, skeletal, tomography, transcatheter aortic valve replacement, X-ray computed

INTRODUCTION

Severe aortic stenosis (AS) is one of the most prevalent degenerative valvular heart diseases in the elderly population and has traditionally been managed with surgical aortic valve replacement (SAVR).¹ However, in elderly patients with multiple comorbidities, this approach may be associated with substantially higher perioperative morbidity and mortality.² Since 2002, transcatheter aortic valve implantation (TAVI) has emerged as a less invasive alternative and is currently accepted as the first-line treatment in symptomatic high-risk and selected asymptomatic patients.^{3–6} Despite its minimally invasive nature, TAVI carries inherent procedural and postoperative risks, including conduction disturbances and the need for permanent pacemaker implantation (PPI).⁷ However, the broader adoption of TAVI over SAVR is contingent upon reducing the incidence of paravalvular regurgitation, stroke, and PPI to levels comparable with those achieved with surgical

ORIGINAL INVESTIGATION

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replacement.^{6,8} Accurate risk stratification in patients being considered for TAVI remains an ongoing clinical challenge.

Although published evidence suggests that post-TAVI complications may be associated with alterations in body composition, the precise magnitude, clinical boundaries, and optimal assessment method of this relationship have yet to be established. Against this background, the present study aims to evaluate the association between body composition parameters derived from routine pre-procedural computed tomography angiography (CTA) and postoperative mortality, morbidity, permanent cardiac conduction defect (PCCD), and PPI requirement in patients undergoing TAVI.

METHODS

Study Design and Patient Population

Patients with symptomatic severe AS who underwent TAVI at a single tertiary referral center between January 2018 and February 2024 were enrolled in this retrospective cohort study. Treatment decisions were made in accordance with current European Society of Cardiology/European Association for Cardio-Thoracic Surgery (ESC/EACTS) Guidelines for the management of valvular heart disease,^{9,10} following multidisciplinary Heart Team consensus involving cardiac anesthesiologists, cardiac surgeons, and cardiologists. All procedures were performed by a dedicated team of 2 experienced operators, each with a minimum of 14 years of TAVI experience and an annual case volume exceeding 40 procedures. The following prostheses were utilized throughout the study period: balloon-expandable Edwards SAPIEN-XT/SAPIEN-3 (Edwards Lifesciences, Irvine, CA), balloon-expandable Meril Myval (Meril Life Sciences Pvt. Ltd., Vapi, India), self-expanding ACURATE neo (Boston Scientific, Marlborough, MA, USA), self-expanding Portico (Abbott Structural Heart, St. Paul, MN, USA), and the self-expanding Medtronic CoreValve/Evolut-R system (Medtronic, Minneapolis, MN). Bioprosthesis sizing was determined primarily on the basis of computed tomography (CT) and echocardiographic findings. Device endpoints, procedural success, and related adverse events were documented in accordance with Valve Academic Research Consortium-3 definitions.¹¹

HIGHLIGHTS

- Pre-procedural computed tomography angiography may facilitate body composition analysis in transcatheter aortic valve implantation (TAVI) patients without additional cost or radiation exposure.
- Lower muscle area (MA) and MA/body mass index ratio were independently associated with cardiac mortality in men, with no such association observed in women.
- Lower subcutaneous adipose tissue area and total adipose tissue area were independently associated with permanent cardiac conduction defect in women on multiple analysis.
- Sex-blind risk assessment may overlook divergent body composition profiles with distinct prognostic implications in TAVI.

Of the 244 patients who underwent TAVI at the authors' institution, a total of 43 patients did not undergo pre-procedural CTA and were therefore excluded from the study. The reasons for the absence of pre-procedural CTA included renal impairment (n=13), the availability of previous peripheral angiographic imaging (n=11), and unspecified reasons for the remaining patients (n=19). Two hundred one patients were comprehensively evaluated with CTA to assess for peripheral arterial disease, determine aortic annulus dimensions, and characterize the anatomical relationship between the aortic valve annulus and the coronary ostia.

Eligible patients were adults aged 18 years or older who underwent TAVI and had available pre-procedural CTA scans suitable for body composition analysis at the L3 vertebral level. A total of 27 patients were excluded due to technically inadequate CTA images: 12 had suboptimal image quality or motion artifacts, 10 had an incomplete field of view (FOV) at L3, and 5 had significant metallic interference. An additional 3 patients were excluded due to insufficient clinical follow-up data. The final analytic cohort comprised 171 patients. The study flowchart is presented in Figure 1.

Computed Tomography Imaging

Computed tomography imaging was performed using a 64-detector multidetector CT scanner (32 × 2) (Philips Brilliance-64, Big Bore, version 3.x). All patients were positioned supine. The parameters for scanning and reconstruction were as follows: beam pitch 1; reconstruction kernel 170 f and 130 f; reconstruction slice thickness 3 mm and 2 mm; matrix 512 × 512; FOV 350 mm; acquisition slice thickness 0.75 mm; tube voltage 120 kV; tube current quality reference value of 74 mA with automatic dose modulation program. Images were reformatted in the axial, coronal, and sagittal planes and subsequently archived in the Picture Archiving and Communication System. Pre-procedural CTA was performed as part of the routine TAVI work-up, typically within 3-7 days before the procedure.

Image Interpretation

Prior to analysis, all patient-identifying information was systematically removed from the CT images. Following transfer to a dedicated workstation, segmentation analysis was performed on a single axial cross-section at the L3 vertebral level. The L3 level was selected because a single cross-sectional slice at this level correlates strongly with whole-body skeletal muscle and adipose tissue volume.¹² The psoas muscle, abdominal wall musculature including autochthonous back muscles, and quadratus lumborum muscle were automatically segmented within a predefined Hounsfield unit (HU) range of -29 to +150 HU. Subcutaneous adipose tissue area (SATA) and visceral adipose tissue area (VATA) were similarly segmented using predefined HU thresholds of -30 to -250 HU. Segmentation was performed using AsanJ software (Version 1.54, Asan Medical Center, South Korea), an open-source plugin based on ImageJ (National Institutes of Health, Bethesda, MD, USA). All measured muscle and adipose tissue areas were recorded on standardized data collection forms. Tissue attenuation values for visceral adipose tissue (VATA HU), subcutaneous adipose tissue (SATA HU), and the psoas

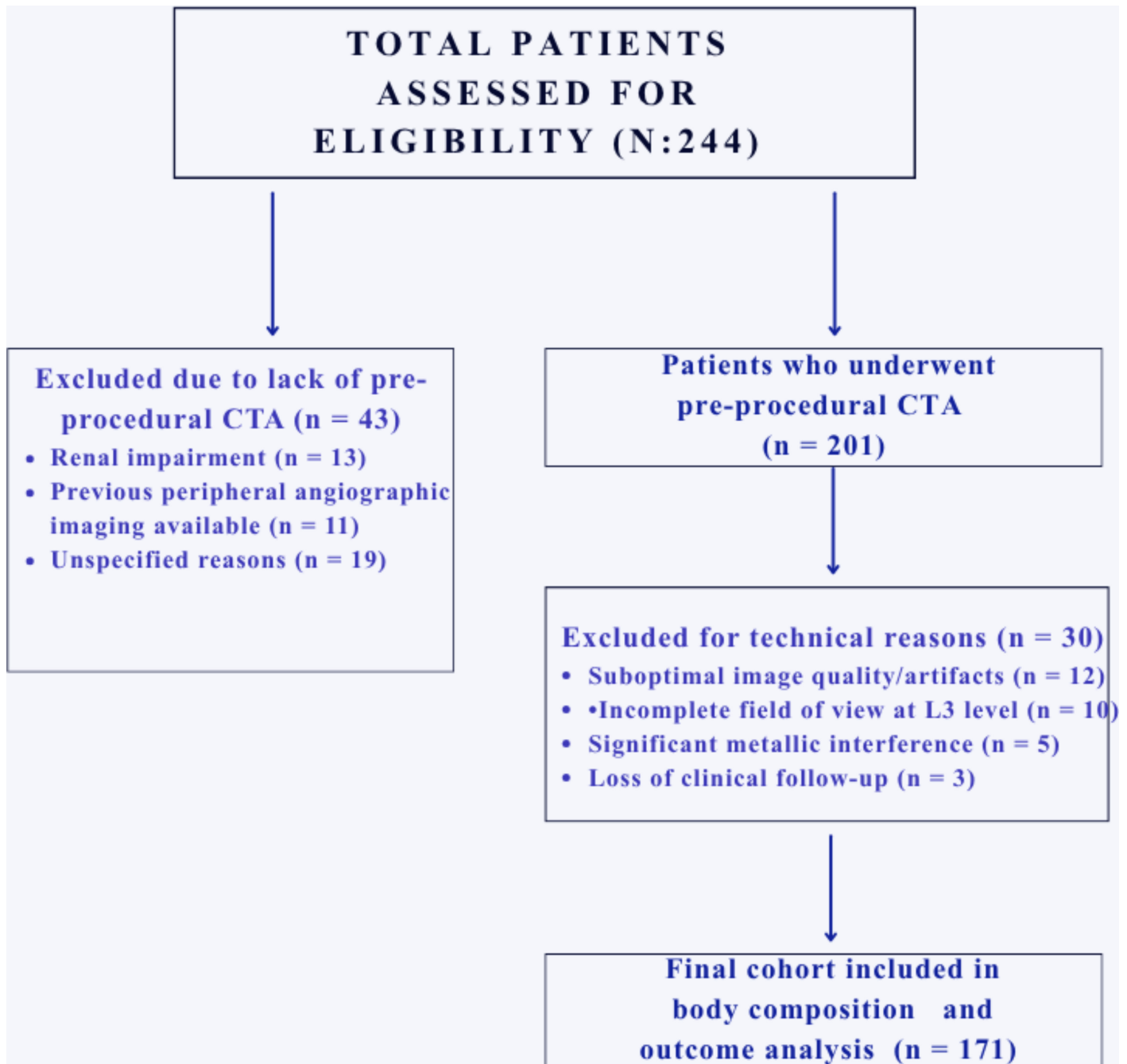


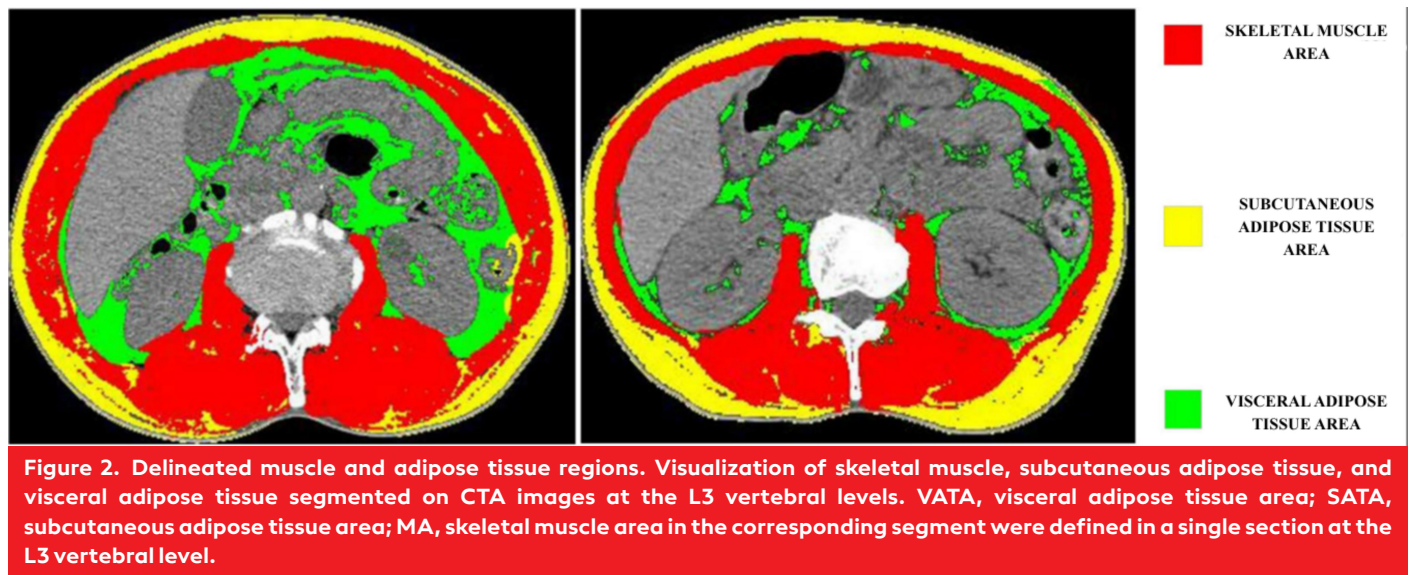
Figure 1. Flowchart for screening and study selection process.

muscle were also recorded. All measurements were independently performed by 2 experienced radiologists, (each with a minimum of 5 years of dedicated radiology experience), who were blinded to patient clinical data, and were subsequently verified by a senior radiologist. Visceral adipose tissue area, SATA, and MA were each defined at a single cross-section at the L3 vertebral level. The sum of SATA and VATA was designated as total adipose tissue area (TATA). The delineated muscle and adipose tissue regions are illustrated in Figure 2.

Procedural Details and Post-Procedural Follow-up

All TAVI procedures were performed using standard techniques. The transfemoral approach was used in the majority

of cases; 2 patients underwent TAVI via the axillary access route. Valve type selection—balloon-expandable or self-expanding—was determined according to individual patient anatomy and Heart Team consensus. All patients were monitored in the intensive care unit under continuous telemetric surveillance for a minimum of 24-48 hours postoperatively. Mortality data and causes of death were obtained through the national medical records system. The occurrence of PCCD and the requirement for PPI were determined by retrospective review of electrocardiograms (ECG) recorded during routine outpatient follow-up visits, accessed via the hospital information system. Indications for PPI in cases of new-onset conduction disturbances or complete heart block



were established in accordance with the 2013 and 2021 ESC Guidelines on Cardiac Pacing and Cardiac Resynchronization Therapy.^{13,14}

Endpoints

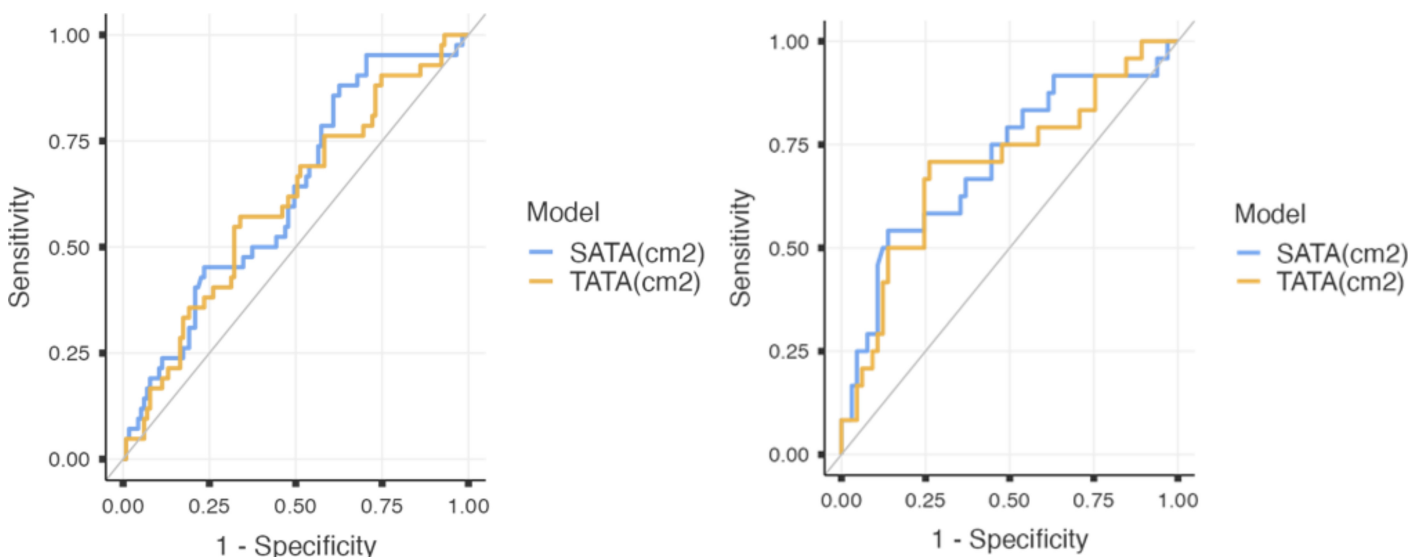
The primary endpoints were all-cause mortality and cardiac mortality. Cardiac mortality was defined as death attributable to cardiovascular causes, including heart failure, sudden cardiac death, and valve-related complications. Secondary endpoints comprised new-onset PCCD, PPI requirement, and total length of hospital stay, all assessed within the first 30 days following the procedure.

Patients with a pre-existing permanent pacemaker at baseline were excluded from the PPI endpoint analysis. Permanent cardiac conduction defect was defined as new-onset conduction disturbance meeting any of the following

criteria: (1) in patients with normal baseline conduction, the development of a new bundle branch block (BBB), new first-degree atrioventricular (AV) block, high-degree or complete AV block, or the requirement for PPI; (2) in patients with pre-existing first-degree AV block, an increase in PR interval of >20 ms or the development of an additional BBB; or (3) in patients with pre-existing BBB, the development of alternating contralateral BBB or new first-degree AV block.

Statistical Analysis

All statistical analyses were performed using the Jamovi software (Version 2.6.26.0). The normality of continuous variables was assessed using the Kolmogorov–Smirnov test. Continuous variables were summarized as either mean $\pm$ SD or median with interquartile range (IQR), depending on the distribution. Normally distributed continuous variables were compared using the Student's *t*-test, while non-normally



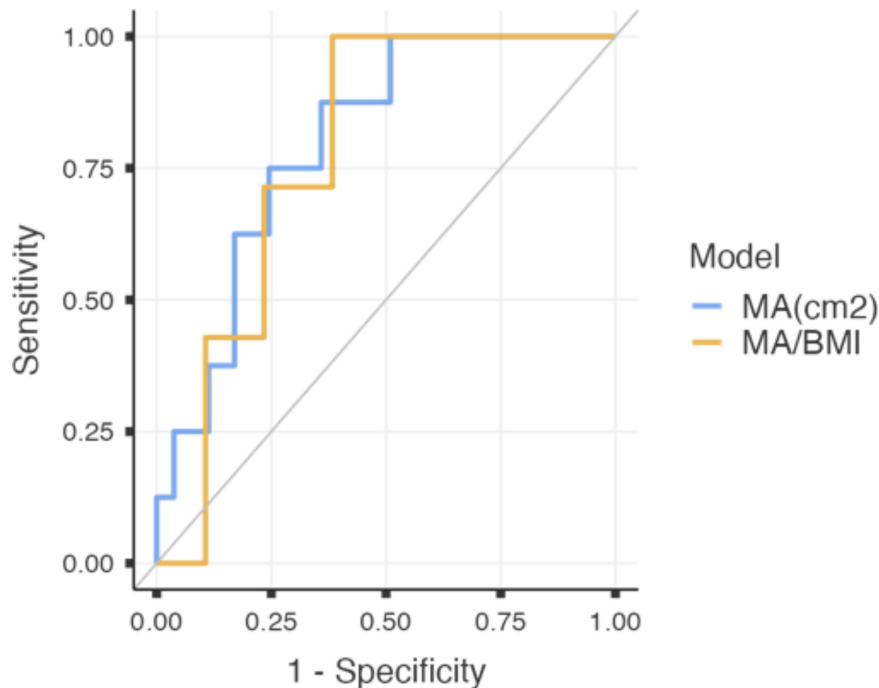


Figure 3 ROC curves of MA and MA/BMI ratio for predicting cardiac mortality in men. BMI, body mass index; MA, muscle area; ROC, receiver operating characteristic.

distributed variables were compared using the Mann–Whitney *U*-test. Categorical variables were compared using the chi-square test or Fisher's exact test, as appropriate. In this study, MA was evaluated as a continuous CT-derived measure of muscle quantity rather than as clinically defined sarcopenia according to consensus diagnostic criteria (e.g., the European Working Group on Sarcopenia in Older People 2 [EWGSOP2] criteria), as functional measures such as hand-grip strength and gait speed were not available in this retrospective cohort.¹⁵ All analyses were performed for the overall cohort and repeated separately for male and female patients to account for sex-specific differences in body composition.

Univariate logistic regression analyses were performed to identify potential predictors of all-cause mortality, cardiac mortality, post-operative PCCD, and PPI requirement. Variables with a *P*-value of less than .10 in univariate analyses, along with clinically relevant covariates, were entered into the multiple logistic regression model using the forced-entry method. Results were expressed as odds ratios (ORs) with corresponding 95% CIs. Receiver operating characteristic (ROC) curve analysis was performed to evaluate the discriminative performance of significant body composition parameters in female patients. The optimal cut-off value, determined by the Youden Index, along with sensitivity, specificity, and the area under the curve (AUC) was calculated for each parameter. A *P*-value of <.05 was considered statistically significant. Complete regression outputs and ROC curve analyses are provided as Supplementary Tables S1–S10.

RESULTS

A total of 171 patients who underwent elective TAVI between January 2018 and February 2024 were included

in this study. The study population consisted of 95 female (55.5%) and 76 male (44.5%) patients, with a median age of 78.9 years (IQR = 75.0–83.0) and a mean follow-up duration of 21.8 ± 17.9 months. The median society of thoracic surgeons (STS) score was 6.30 (IQR = 4.37–9.33). Muscle area (MA) was significantly lower in female patients (82.4 ± 19.8 cm²) compared to male patients (107 ± 20.5 cm²) ($P < .001$), whereas SATA was significantly higher in females (170 cm², IQR = 126–230 vs. 138 cm², IQR = 95–186; $P = .001$). Detailed patient demographics and baseline comorbidities are presented in Table 1.

Primary Outcome

The median total hospital stay was 4 days (IQR = 4.0–5.0). During follow-up, 43 patients (25.1%) died, of whom 12 (7.0%) died from cardiac causes (Table 2). All-cause and cardiac mortality rates did not differ significantly between sexes ($P = .305$ and $P = .103$, respectively). In the overall cohort, lower MA was significantly associated with all-cause mortality (86.6 vs. 95.1 cm², $P = .043$). This association was also observed in sex-specific analyses, with lower MA remaining significantly associated with all-cause mortality in both men (98.9 vs. 109.7 cm², $P = .045$) and women (74.8 vs. 84.6 cm², $P = .045$). The MA/BMI ratio was also significantly lower among women who died compared to survivors (254.7 vs. 306.8, $P = .047$), whereas it did not reach statistical significance in men (367.4 vs. 410.2, $P = .094$) (Table 3). Although MA was identified as a significant predictor of all-cause mortality in univariate analysis, it did not retain statistical significance in multiple analysis (Table S1). In ROC curve analysis, MA did not demonstrate significant discriminative performance in the overall cohort (AUC = 0.595, $P = .064$) or in female patients (AUC = 0.384,

Table 1. Baseline Patient Demographics and Clinical Characteristics

		Total n = 171	Male n = 76 (44.5%)	Female n = 95 (55.5%)	P
Age, year (IQR)		78.9 (75.0-83.0)	80 (74.8-82.3)	80 (75.8-83.0)	.336
Follow up period, months		21.8 ± 17.9	22.3 ± 18.7	21.3 ± 17.4	.916
STS score (IQR)		6.30 (4.37-9.33)	5.6 (4.25-9.49)	6.4 (4.68-9.32)	.339
Diabetes		70 (41.7)	29 (38.1)	41 (43.1%)	.479
Hypertension		111 (64.9)	44 (57.8)	67 (70.5)	.054
Malignancy		1 (0.5)	0 (0)	1 (1.0)	.365
Coronary artery disease		81 (47.3)	40 (52.6)	41 (43.1)	.269
Previous cerebrovascular event		3 (1.7)	1 (1.3)	2 (2.1)	.683
Peripheral artery disease		19 (11.1)	10 (13.1)	9 (9.4)	.476
COPD		25 (14.6)	16 (21.0)	9 (9.4)	.036
Chronic kidney disease		45 (26.3)	23 (30.2)	22 (23.2)	.334
Previous conduction defect		26 (15.2)	18 (23.6)	8 (8.4)	.004
RBBB		6 (3.5)	4 (5.2)	2 (2.1)	.486
LBBB		12 (7.0)	5 (6.5)	7 (7.3)	
1 st degree AV block		12 (7.0)	7 (9.2)	5 (5.2)	.509
Previous pacemaker		10 (5.8)	7 (9.2)	3 (3.1)	.094
Previous AF		37 (21.6)	15 (19.7)	22 (23.1)	.627
LVEF (IQR)		60 (50.0-60.0)	55 (37.5-60.0)	60 (55.0-65.0)	<.001
Hgb (g/dL)		11.5 (± 1.9)	12.1 (± 2.1)	11.0 (± 1.7)	<.001
Albumin (g/dL) (IQR)		3.8 (3.5-4.1)	3.9 (3.6-4.1)	3.8 (3.5-4.1)	.187
Creatinine (mg/dL) (IQR)		1.10 (0.9-1.4)	1.25 (1.0-1.5)	1.02 (0.9-1.2)	<.001
GFR		54.0 (± 17.7)	55.1 (± 18.6)	53.0 (± 17.0)	.447
CRP (IQR)		3.0 (1.0-11.4)	4.0 (1.8-15.5)	3.0 (1.0-9.0)	.052
BMI (IQR)		27.4 (25.0-30.0)	27.0 (24.1-29.0)	27.7 (25.5-31.2)	.037
MA (cm ²)		93.0 (± 23.4)	107 (± 20.5)	82.4 (± 19.8)	<.001
VATA (cm ²) (IQR)		158.8 (98.4-224.0)	181 (± 98.2)	155 (± 75.5)	.058
SATA (cm ²) (IQR)		158.7 (113-205)	138 (95-186)	170 (126-230)	.001
TATA (cm ²)		329.6 (± 149)	327 (± 150)	343 (± 149)	.483
MA/TATA (IQR)		0.281 (0.207-0.413)	0.337 (0.246-0.480)	0.232 (0.182-0.365)	<.001
MA/VATA (IQR)		0.594 (0.411-0.881)	0.657 (0.434-1.01)	0.557 (0.384-0.842)	.099
MA/SATA (IQR)		0.611 (0.399-0.895)	0.790 (0.578-1.03)	0.482 (0.314-0.719)	<.001
MA/BMI		342 (± 104)	399 (± 88.2)	296 (± 93.5)	<.001
Valve type	Myval	116 (67.8)	53 (69.7)	63 (66.3)	.48
	Accurate Neo	19 (11.1)	8 (10.5)	11 (11.5)	
	Edward Sapiens	23 (13.5)	8 (10.5)	15 (15.7)	
	Portigo	2 (1.2)	2 (2.6)	0 (0)	
	Evolut R	11 (6.4)	5 (6.5)	6 (6.3)	
Valve expansion	Self expandable	36 (21.0)	18 (23.6)	18 (18.9)	.369
	Balloon-expandable	135 (78.9)	58 (76.3)	77 (81.0)	
Valve size	S	68 (39.8)	9 (11.8)	59 (62.1)	<.001
	M	62 (36.2)	33 (43.4)	29 (30.5)	
	L	41 (24.0)	34 (44.7)	7 (7.3)	
Valve placement	Normal placement	129 (75.4)	51 (67.1)	78 (82.1)	.086
	Deep LVOT	36 (21.0)	20 (26.3)	16 (16.8)	
Dilatation	Balloon predilatation	107 (62.5)	50 (65.7)	57 (60.0)	.24
	Balloon postdilatation	16 (9.3)	7 (9.2)	9 (9.4)	

AF, atrial fibrillation; COPD, chronic obstructive pulmonary disease; GFR, glomerular filtration rate; LBBB, left bundle branch block; LVEF, left ventricular ejection fraction; LVOT, left ventricular outflow tract; MA, muscle area; RBBB, right bundle branch block; SATA, subcutaneous adipose tissue area; STS score, society of thoracic surgeons score; TATA, total adipose tissue area; VATA, visceral adipose tissue area.

Table 2. Overall Clinical End Points

	Total	Male	Female	P
Total mortality (%)	43 (25.1)	22 (28.9)	21 (22.1)	.305
Cardiac mortality (%)	12 (7.0)	8 (10.5)	4 (4.2)	.103
Post-op PCCD (%)	44 (27.7)	19 (25.0)	25 (26.3)	.973
Post-op PPI (%)	30 (18.6)	14 (18.4)	16 (16.8)	.640
Post-op clinic days	3 (1.75-3.0)	3 (2.0-4.0)	3 (1.0-3.0)	.067
Total hospital stay, days	4 (4.0-5.0)	4 (4.0-6.0)	4 (4.0-5.0)	.056

PCCD, permanent cardiac conduction disturbance; PPI, permanent pacemaker implantation.

$P=.127$). The MA/BMI ratio similarly approached but did not reach significance for all-cause mortality in women (AUC = 0.662, $P=.055$) (Table S2).

Data are presented as median. Differences between groups were tested with the Student's *t*-test or the Mann-Whitney U test, as appropriate. Bold *p* values indicate statistical significance ($p<0.05$). BMI, body mass index; CT, computed tomography; MA, muscle area.

With respect to cardiac mortality, the association between MA and cardiac mortality did not reach statistical significance in the overall cohort (81.7 vs. 95.1 cm², $P=.051$). In male patients, however, those who died from cardiac causes had significantly lower baseline MA (89.0 vs. 109.7 cm², $P=.020$) and MA/BMI ratio (325.0 vs. 404.6, $P=.026$). In contrast, no significant association was observed between MA and cardiac mortality in female patients (66.9 vs. 84.6 cm², $P=.077$), nor between MA/BMI ratio and cardiac mortality in women (239.4 vs. 306.8, $P=.180$), underscoring the sex-specific nature of these findings. In both univariate and multiple logistic regression analyses—the latter adjusted for age, STS score, and GFR—lower MA (adjusted OR = 0.935, $P=.016$, 95% CI = 0.886-0.987) and lower MA/BMI ratio (adjusted OR = 0.983, $P=.042$, 95% CI = 0.967-0.999) remained independently associated with cardiac mortality in male patients (Table S3). In ROC curve analysis, MA demonstrated good discriminative performance for cardiac mortality in men (AUC = 0.800, $P<.001$, 95% CI = 0.662-0.938 (sensitivity: 87.5% and specificity: 64.2%), in marked contrast to the absence of discriminative capability observed in female patients (AUC = 0.384, $P=.127$) (Figure 3). The MA/BMI ratio yielded an AUC = 0.778, $P<.001$, 95% CI = 0.645-0.911, with a sensitivity of 100% in men (Table S4).

Secondary Outcome

For the evaluation of post-operative secondary endpoints, 10 patients with preexisting permanent pacemakers at baseline were excluded from the analysis. Post-operative conduction defects occurred in 44 patients (27.7%), with no sex-based difference ($P=.973$). Valve type was also not significantly associated with the development of PCCD (Fisher's exact test, $P=.236$; Supplementary Table 6). In the overall cohort, lower SATA was significantly associated with PCCD (143.4 vs. 179.1 cm², $P=.019$), as was lower TATA (297.4 vs. 350.8 cm², $P=.043$). In the female cohort, patients who developed post-operative conduction defects exhibited significantly lower baseline SATA (142.8 vs. 203.9 cm², $P=.003$) and TATA (266.7 vs. 364.8 cm², $P=.004$), alongside significantly higher MA/SATA (0.879 vs. 0.496, $P=.005$) and MA/TATA (0.470 vs. 0.266, $P=.007$) ratios. Visceral adipose tissue area did not reach statistical significance in this subgroup (128.5 vs. 160.9 cm², $P=.066$). No significant associations were observed between body composition parameters and PCCD in male patients (Table 4). Following multiple adjustments controlling for valve size, placement, pre- and post-dilatation, and baseline conduction blocks, SATA (OR = 0.990, $P=0.031$, 95% CI = 0.981-0.999) and TATA (OR = 0.994, $P=0.024$, 95% CI = 0.989-0.999) were independently associated with lower odds of PCCD in women on multiple analyses (Table S5). Receiver operating characteristic curve analysis demonstrated that SATA (AUC = 0.710, $P=.001$) and TATA (AUC = 0.697, $P=.003$) provided modest discriminative ability for PCCD in women (Figure 4). Subcutaneous adipose tissue area achieved a notably high specificity of 86.2% at a cut-off value of 123.3 cm², while TATA yielded a sensitivity of 73.6% and specificity of 70.1% at a cut-off of 285.4 cm² (Table S6).

Permanent pacemaker implantation was required in 30 patients (18.6%), with no significant sex-based difference ($P=.640$) (Table 2). No significant association was observed between valve type and PPI requirement (Fisher's exact test, $P=.413$; Supplementary Table 8). In the overall cohort, lower SATA (139.5 vs. 179.5 cm², $P=.027$) and TATA (291.0 vs. 351.7 cm², $P=.049$) were significantly associated with PPI requirement. In female patients, those requiring PPI exhibited significantly lower VATA (115.0 vs. 166.4 cm², $P=.013$), SATA (138.3 vs. 199.1 cm², $P=.021$), and TATA (253.3 vs. 364.5 cm², $P=.007$), as well as higher MA-to-fat tissue ratios (all $P\leq .012$). Higher baseline STS scores were also associated with PPI in women (9.4 vs. 7.3, $P=.040$). In male patients, the MA/BMI ratio was lower among those requiring PPI compared to those who did

Table 3. Association of CT-derived body composition parameters with primary endpoints (all-cause and cardiac mortality) according to sex

		Male			Female			Total		
		Death	Survived	P	Death	Survived	P	Death	Survived	P
Total mortality	MA (cm ²)	98.9	109.7	.045	74.8	84.6	.045	86.6	95.1	.043
	MA/BMI ratio	367.4	410.2	.094	254.7	306.8	.047	311.1	350.9	.057
Cardiac mortality	MA (cm ²)	89.0	109.7	.020	66.9	84.6	.077	81.7	95.1	.051
	MA/BMI ratio	325.0	404.6	.026	239.4	306.8	.180	293.9	350.9	.084

Table 4. Association of CT-derived body composition parameters and STS score with secondary endpoints (post-operative cardiac conduction disturbance and need for permanent pacemaker implantation) according to sex.

		Male			Female			Total		
		Yes	No	P	Yes	No	P	Yes	No	P
Post-op cardiac conduction disturbance	MA (cm ²)	103.7	107.6	.487	84.4	82.1	.614	92.5	93.2	.867
	VATA (cm ²)	194.3	185.7	.749	128.5	160.9	.066	156.1	171.7	.316
	SATA (cm ²)	144.1	146.9	.869	142.8	203.9	.003	143.4	179.1	.019
	TATA (cm ²)	338.5	332.6	.883	266.7	364.8	.004	297.4	350.8	.043
	STS score	8.2	7.2	.902	8.9	7.4	.134	8.574	7.295	.314
Post-op need for permanent pacemaker implantation	MA (cm ²)	103.1	107.0	.543	83.9	81.9	.725	92.5	92.5	.957
	VATA (cm ²)	196.4	181.9	.639	115.0	166.4	.013	151.5	172.8	.237
	SATA (cm ²)	140.9	151.7	.620	138.3	199.1	.021	139.5	179.5	.027
	TATA (cm ²)	337.4	333.6	.935	253.3	364.5	.007	291.0	351.7	.049
	STS score	9.6	7.3	.208	9.4	7.3	.040	9.45	7.3	.024

Values are presented as median. Differences between groups were tested with the Student's t-test or the Mann–Whitney U test, as appropriate. Bold *p* values indicate statistical significance (*p* < 0.05). BMI, body mass index; MA, muscle area; PPI, permanent pacemaker implantation; SATA, subcutaneous adipose tissue area; STS score, society of thoracic surgeons score; TATA, total adipose tissue area; VATA, visceral adipose tissue area.

not (343.4 vs. 406.9, *P* = .026); however, this association did not persist after multiple adjustment. Although VATA, SATA, TATA, the MA-to-fat ratios, and the STS score were identified as statistically significant markers in univariate analyses, none maintained independent predictive significance after multiple regression adjustment in either sex (Table S7). In women, SATA (AUC: 0.726, *p* = 0.008), TATA (AUC: 0.708, *p* = 0.011), and VATA (AUC: 0.696, *p* = 0.016) showed modest discriminative ability for PPI (Table S8).

DISCUSSION

In this retrospective, single-center cohort of 171 TAVI patients, CT-derived body composition parameters derived from routine pre-procedural CTA demonstrated sex-specific associations with postoperative outcomes. Lower MA was associated with all-cause mortality across the cohort, though without independent significance on multiple adjustment.

Aortic stenosis is associated with substantial morbidity and mortality, and whereas TAVI has markedly improved survival and quality of life in high-risk patients,^{16–18} procedure-related complications—particularly new-onset conduction disturbances and PPI requirement—remain prevalent and have not declined significantly compared to other adverse outcomes.¹⁹ Critically, no single validated risk score or biomarker suitable for routine clinical use is currently available to predict these complications, underscoring the need for additional, readily applicable predictors. The all-cause mortality rate of 25.1% observed in this study's cohort over a mean follow-up of 21.8 months is consistent with published data from comparable high-risk TAVI populations,⁴ and the median STS score of 6.30 reflects the elevated surgical risk profile of the study population. Although the STS score was not specifically developed for TAVI, it remains partially informative given its broad comorbidity coverage.²⁰

Computed tomography and MRI are regarded as gold-standard modalities for body composition assessment owing to their capacity to differentiate muscle from adipose tissue

with high precision. Although their standalone use is constrained by cost and availability, the pre-procedural CTA routinely performed in TAVI patients constitutes a ready imaging source for body composition analysis without incurring additional cost or radiation exposure.^{21–23}

The prognostic relevance of sarcopenia and CT-derived body composition in TAVI has attracted growing interest in recent literature.^{24–28} Garg et al²⁹ demonstrated that sarcopenia, as defined by the psoas MA/BMI ratio, was independently associated with adverse TAVI outcomes. Soh et al³⁰ reported—in contrast to the authors' findings—that adipose tissue loss, alongside sarcopenia, was significantly associated with 1-year post-procedural mortality. Ricci et al³¹, meanwhile, identified sarcopenia as an adverse prognostic marker while proposing that obesity may confer a protective role consistent with the “obesity paradox.” Collectively, these studies highlight the prognostic relevance of both muscle and adipose tissue in TAVI populations and provide the conceptual basis for the present study's hypothesis that detailed, sex-specific body composition assessment—encompassing both muscle and adipose tissue compartments—may be independently associated with distinct postoperative outcomes.

In the overall cohort and across sex-specific subgroups, lower MA was significantly associated with all-cause mortality; however, this association did not persist after multiple adjustments for age, STS score, and GFR. This suggests that MA may reflect overall frailty burden rather than constituting an independent mortality predictor in this population. In male patients, however, lower MA and MA/BMI ratio remained independently associated with cardiac mortality in multiple analyses. This sex-specific pattern is consistent with published data on divergent sarcopenia phenotypes between men and women and suggests that skeletal muscle depletion may carry a more direct prognostic significance for cardiac outcomes in men than in women.^{32–36} A plausible biological basis for this divergence relates to the androgen-dependent regulation of skeletal muscle in men: testosterone declines progressively with age and acts directly on

the androgen receptor expressed in myonuclei and satellite cells, and this decline has been consistently associated with reduced muscle mass, strength, and frailty in older men.³⁷ Whether this hormonal pathway underlies the sex-specific association observed in this study's cohort cannot be determined from the present data, as hormonal parameters were not measured.

In men, cardiac-related mortality was associated with a lower baseline MA (89.0 cm² among those who died vs. 109.7 cm² among survivors) and a lower MA/BMI ratio (325.0 vs. 404.6), consistent with the descriptive comparisons reported above. On ROC curve analysis, MA and MA/BMI ratio demonstrated exploratory discriminative performance for cardiac mortality (MA: AUC=0.800, sensitivity 87.5%, specificity 64.2%, cut-off 104.4 cm²; MA/BMI: AUC=0.778, sensitivity 100%, specificity 61.7%, cut-off 383.1). Although previous TAVI cohorts have applied externally derived skeletal muscle index thresholds originally established in oncologic populations,³⁸ the authors did not apply these cutoffs to reclassify this study's cohort, given the anatomical and methodological differences discussed above; instead, the authors report the cohort-derived, exploratory cutoffs above, obtained via ROC/Youden analysis. For PCCD in women, SATA (AUC=0.710, cut-off 123.3 cm², *P*=.001) and TATA (AUC=0.697, cut-off 285.4 cm², *P*=.003) similarly provided modest discriminative ability (Supplementary Data). These values require prospective validation in larger cohorts before clinical application and are presented as hypothesis-generating reference points for future sex-specific risk stratification studies in TAVI.

The authors further note that previous TAVI studies assessing body composition have predominantly relied on isolated psoas muscle measurements, often obtained at the fourth lumbar vertebra, whereas the present study assessed the total musculature at L3. This methodological distinction may be relevant, as psoas cross-sectional area has been reported to correlate only moderately with whole L3-slice skeletal MA (*r*=0.70), compared with the anterior abdominal wall and paravertebral musculature (*r*=0.93 and *r*=0.89, respectively), and has been described in the literature as a limited surrogate for total muscle mass.³⁹ Whether this methodological difference contributes to the discrepancies between the findings of this study and those of prior TAVI studies relying on isolated psoas measurements cannot be determined from the present retrospective data and would require dedicated comparative studies.

Female patients exhibited significantly lower MA (82.4 ± 19.8 cm²) and higher TATA (343 ± 149 cm²) compared to men, reflecting a body composition pattern often described in the literature as sarcopenic obesity, although sarcopenia itself was not formally diagnosed per consensus criteria in this study.^{40,41} Notably, despite the lower MA/TATA ratios in women, this phenotype was not independently associated with mortality. Rather, in female patients, higher adipose tissue area was inversely associated with PCCD—a pattern consistent with the broader obesity paradox observed in cardiovascular disease—though the mechanistic basis of

this association in the specific context of post-TAVI conduction disturbances remains to be determined. One candidate contributor is hormonal: in postmenopausal women, adipose tissue becomes a major site of estrogen synthesis via aromatization and can account for a substantial proportion of circulating estrogen in this population.⁴² Estrogen exerts broad cardiovascular effects, including direct receptor-mediated actions on vascular and endothelial tissue.⁴³ Whether greater adipose reserve confers relative protection against post-TAVI conduction disturbances through this pathway is speculative and was not directly tested in the present retrospective cohort, warranting dedicated hormonal investigation in future studies. In multiple analyses, lower SATA and TATA were independent predictors of PCCD in female patients (SATA OR=0.990, *P*=.031; TATA OR=0.994, *P*=.024), with ROC curve analysis confirming modest discriminative performance for both parameters (SATA AUC=0.710; TATA AUC=0.697). The incidence of PCCD (27.7%) and PPI requirement (18.6%) in this study's cohort are consistent with published literature, and while post-TAVI conduction disturbances are traditionally attributed to procedural and anatomical factors such as prosthesis type, implantation depth, and valve size,^{44,45} the present findings suggest that pre-procedural body composition may represent an additional, sex-specific variable independently associated with conduction outcomes, beyond the procedural and baseline conduction covariates included in this study's multiple model.

The absence of significant associations between body composition parameters and PCCD or PPI in male patients warrants consideration. In men, cardiac mortality was the primary outcome associated with body composition, driven by muscle depletion rather than adipose tissue distribution. One plausible explanation for this divergence is the systematically different body composition phenotype between sexes: men in this cohort exhibited higher MA and lower adipose tissue indices, which may have resulted in insufficient variation in fat parameters to detect associations with conduction outcomes. However, this interpretation is speculative and warrants prospective investigation. The sex-specific nature of the adipose tissue—conduction disturbance relationship therefore appears biologically plausible and consistent with published evidence on sex differences in body composition and cardiovascular risk.

The findings of this study indicate that clinical risk assessment in TAVI should extend beyond BMI. The divergent sex-specific prognostic roles of muscle and adipose tissue—lower MA associated with cardiac mortality in men, and lower adipose tissue area associated with conduction disturbances in women—support the development of sex-specific body composition thresholds as complementary tools to conventional risk scores. In patients at elevated risk of requiring post-procedural pacing, these parameters may inform pre-procedural planning, including the selection of implantation depth, as well as post-procedural surveillance strategies, such as extended telemetric or ECG monitoring in women with reduced adipose tissue reserve and closer clinical attention to cardiac risk in men with low MA. This consideration carries additional relevance, as high-grade AV block

has recently been shown to independently predict systemic perfusion impairment in patients with symptomatic bradycardia, alongside advanced age and lower heart rate.⁴⁶ Early identification of patients at elevated risk of developing high-grade AV block after TAVI may therefore allow for closer monitoring and more timely temporary pacing or PPI before hemodynamic compromise develops. However, prospective studies in larger, standardized cohorts are required before such parameters can influence routine clinical practice.

Limitations of the Study

Several limitations should be considered when interpreting the findings of this study. The single-center, retrospective design limits external validity, and the restriction to recorded clinical and imaging data precludes the standardization afforded by prospective data collection protocols. The substantial variability in follow-up duration (mean 21.8 ± 17.9 months) introduces a heterogeneous observation window that may affect the precision of mortality estimates. The sample size limits statistical power, particularly in sex-specific subgroup analyses, and caution is warranted in the interpretation of certain findings. Although segmentation analyses were performed independently by 2 radiologists, interobserver agreement coefficients were not reported; this should be addressed in future studies to facilitate methodological standardization. Finally, MA reflects only 1 component of frailty and does not encompass comprehensive geriatric assessment parameters, including handgrip strength. Consequently, the lower MA evaluated in this study should be interpreted as a quantitative imaging-derived indicator of muscle mass rather than a clinically diagnosed sarcopenia phenotype. Additionally, although valve type was not significantly associated with either PCCD or PPI requirement in this cohort (Supplementary Tables 9-10), the present analysis did not examine the potential influence of age on pacemaker requirement or the distinction between early- and late-onset conduction block—factors that warrant dedicated investigation in future studies.

Nutritional status can independently influence both muscle and adipose tissue mass and was not comprehensively assessed in this cohort. Serum albumin, a potential surrogate marker, was missing in 39 patients; given the relatively modest size of the overall cohort, incorporating this variable risked introducing spurious or unstable associations, and it was therefore excluded from the analysis. Prealbumin was not part of routine pre-procedural workup, and gait speed could not be reconstructed retrospectively. More broadly, the present study was not designed to identify the underlying causes of altered body composition, but rather to retrospectively examine the association between pre-procedural body composition and post-TAVI complications. Given this retrospective design, the possibility that nutritional status or other predisposing conditions partly contribute to the reported associations cannot be excluded and warrants exploration in future prospective studies.

CONCLUSION

Computed tomography-derived body composition parameters from routine pre-procedural CTA—specifically, lower MA independently associated with cardiac mortality in men,

and lower adipose tissue area independently associated with conduction defects in women—suggest that sex-specific body composition assessment may offer complementary prognostic value beyond conventional risk stratification in TAVI, pending prospective validation.

Ethics Committee Approval: This study was approved by the Ethics Committee of Antalya Training and Research Hospital (Approval No: 10/4, Date: 20/07/2023).

Informed Consent: Written informed consent was obtained from the patients who agreed to take part in the study.

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SUPPLEMENTARY MATERIAL

Supplementary Table 1. Total Mortality Logistic Regression				
	Univariate Analysis		Multiple Analysis(including age, STS and GFR)	
	Odds Ratio (CI)	P	Odds Ratio (CI)	P
MA (Male)	0.937(0.946-0.1.000)	0.050	0.973(0.933-1.000)	0.072
MA (Female)	0.937(0.947-0.999)	0.049	0.977(0.949-1.01)	0.140
MA (Total)	0.984(0.968-0.999)	0.045	0.987(0.971-1.004)	0.151
MA/BMI (Female)	0.990(0.980-1.000)	0.041	0.991(0.981-1.000)	0.079

Supplementary Table 2. Diagnostic Performance of MA for Total Mortality							
Variables	AUC	Sensitivity	Specificity	PPV	NPV	Cut-off	P
MA (Total)	0.595	26.8%	92.1%	52.4%	79.6%	66.295	0.064
MA (Male)	0.659	85.0%	49.1%	38.6%	89.7%	111.84	0.030
MA (Female)	0.384	47.6%	59.7%	25.0%	80.0%	85.435	0.127
MA/BMI (Female)	0.662	50.0%	93.7%	66.7%	88.1%	226.747	0.055

AUC: Area Under the Curve, PPV: Positive Predictive Value, NPV: Negative Predictive Value

Supplementary Table 3. Cardiac Mortality				
	Univariate Analysis		Multiple Analysis	
	Odds Ratio (CI)	P	Odds Ratio(CI)	P
MA (Male)	0.936 (0.890-0.986)	0.012	0.935(0.886-0.987)	0.016
MA (Total)	0.971 (0.942-1.00)	0.057	0.974(0.945-1.00)	0.091
MA/BMI (Male)	0.985 (0.973-0.998)	0.027	0.983(0.967-0.999)	0.042

Supplementary Table 4. Diagnostic Performance of MA and MA/BMI for Cardiac Mortality							
Variables	AUC	Sensitivity	Specificity	PPV	NPV	Cut-off	P
MA (Male)	0.800	87.5%	64.2%	27.0%	97.1%	104.4	<0.001
MA/BMI (Male)	0.778	100.0%	61.7%	28.0%	100.0%	383.1	<0.001

AUC: Area Under the Curve, PPV: Positive Predictive Value, NPV: Negative Predictive Value

Supplementary Table 5 Post-Op Cardiac Conduction Defect Logistic Regression				
	Univariate Analysis		Multiple Analysis (Valve Size, Placement, Dilatation, Post-Dilatation, Previous AV Block and BBB)	
	Odds Ratio(CI)	P	Odds Ratio(CI)	P
SATA (Female)	0.991(0.983-0.998)	0.009	0.990(0.981-0.999)	0.031
TATA (Female)	0.994(0.990-0.999)	0.008	0.994(0.989-0.999)	0.024
SATA (Total)	0.994(0.989-0.999)	0.020	0.995(0.991.000)	0.103
TATA (Total)	0.997(0.995-1.000)	0.045	0.998)0.995-1.000)	0.119

Supplementary Table 6. Diagnostic Performance of Variables for Post-op Cardiac Conduction Defect							
Variable	AUC	Sensitivity	Specificity	PPV	NPV	Cut-off	P
SATA(Female)	0.710	86.2%	54.2%	83.6%	59.1%	123.33	0.001
TATA(Female)	0.697	73.6%	70.1%	82.3%	50.0%	285.355	0.003
AUC: Area Under the Curve, PPV: Positive Predictive Value, NPV: Negative Predictive Value							

Supplementary Table 7. Post-op Need For Permanent Pacemaker Implantation logistic regression				
	Univariate Analysis		Multiple Analysis (Valve Size, Placement, Dilatation, Post-Dilatation, Previous AV Block And BBB)	
	Odds Ratio(CI)	P	Odds Ratio(CI)	P
VATA(Female)	0.990(0.981-0.998)	0.017	0.992(0.982-1.00)	0.112
SATA(Female)	0.990(0.982-0.999)	0.024	0.993(0.984-1.00)	0.158
TATA(Female)	0.994(0.989-0.998)	0.009	0.995(0.990-1.00)	0.086
STS(Female)	1.096(0.983-1.222)	0.100	1.138(0.999-1.30)	0.051
TATA(Total)	0.997(0.994-1.000)	0.051	0.998(0.994-1.00)	0.166
SATA(Total)	0.993(0.987-0.999)	0.028	0.995(0.988-1.00)	0.133
STS(Total)	1.064(0.997-1.134)	0.060	1.071(0.979-1.171)	0.131

Supplementary Table 8. Diagnostic Performance of Variables for Post-op Need For Permanent Pacemaker Implantation (Women)							
Variable	AUC	Sensitivity (%)	Specificity (%)	PPV (%)	NPV (%)	Cut-off	P
VATA(Female)	0.696	62.5%	82.9%	43.5%	91.3%	103.6	0.016
SATA(Female)	0.726	62.5%	86.7%	50.0%	91.6%	121.0	0.008
TATA(Female)	0.708	68.6%	73.3%	35.5%	91.7%	277.4	0.011
STS(Female)	0.665	87.5%	45.2%	25.9%	94.3%	5.3	0.015
TATA(Total)	0.616	58.6%	68.8%	29.8%	88.0%	277.74	0.056
SATA(Total)	0.644	48.3%	77.3%	32.6%	86.8%	121.0	0.014
STS(Total)	0.633	83.3%	42.5%	25.5%	91.5%	4.8	0.016
AUC: Area Under the Curve, PPV: Positive Predictive Value, NPV: Negative Predictive Value							

Supplementary Table 9. Association Between Valve Type and Post-Operative Conduction Defect				
	Yes	No	Total	p-value
MYVAL	36(81.6%)	73(63.5%)	109(68.6%)	0.236*
Accurate Neo	3(6.8%)	13(11.3%)	15(9.4%)	
Edward Sapiens	2(4.5%)	19(16.5%)	22(13.8%)	
Portigo	0(0%)	2(1.7%)	2(1.3%)	
Evolut R	3(6.8%)	8(7.0%)	11(6.9%)	
Total	44(100%)	115(100%)	159(100%)	
*Fisher's Exact Test				

Supplementary Table 10. Association Between Valve Type and Post-Operative Permanent Pacemaker Implantation				
	Yes	No	Total	<i>P</i>
MYVAL	24(80.0%)	85(64.9%)	109(67.7%)	0.413*
Accurate Neo	3(10.0%)	15(11.5%)	18(11.2%)	
Edward Sapiens	1(3.3%)	20(15.3%)	21(13.0%)	
Portigo	0(0%)	2(1.5%)	2(1.2%)	
Evolut R	2(6.7%)	9(6.9%)	11(6.8%)	
Total	30(100%)	131(100%)	161(100%)	
*Fisher's Exact Test				