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COMPARATIVE COMPUTED-TOMOGRAPHY ASSESSMENT OF CALCIFIC LOAD IN BICUSPID VERSUS TRICUSPID AORTIC VALVES

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ABSTRACT
Introduction: One known cause of left ventricular outflow blockage and a significant predictor of cardiovascular risk is calcification of the aortic valve leaflets. Despite making up only 1-2 percent of the general population, bicuspid aortic valves (BAV) are thought to accelerate mineral deposition due to their altered design. This review compares the burden and distribution of aortic valve calcification (AVC) in patients with bicuspid versus tricuspid valves through the inclusion of computed-tomography outcomes of a recent single-center study.
Materials and Methods: A retrospective analysis was conducted on sixty-one persons who were referred for cardiac CT scans between July and September of 2024. Using Multiplanar reconstructions, valve morphology was categorized, and the Agatston method was used to measure calcium volume. Clinical information was taken out of electronic medical records and examined using SPSS 22.0.
Results: In 65.6% of cases, the cohort (mean age 54.6 ± 12.3 years, 57% male) demonstrated symptoms indicative of AVC. Compared to 38.2% of individuals with tricuspid valves (TAV), half (51.9%) of BAV patients had moderate-to-severe calcification. Higher calcium scores were positively correlated with both hypertension and tobacco use ($p < 0.01$). Angaston grade and CT markers of hemodynamically grave stenosis did not precisely link.
Conclusions: Compared to its tricuspid cousin, BAV shape has a detectable higher calcific burden; however, luminal blockage cannot be anticipated only by calcification. Planning a surgical or Tran's catheter execution still requires multipara metric appraisal.
Keywords: Aortic valve calcification, Bicuspid aortic valve and Tricuspid aortic valve.

INTRODUCTION

Aortic valve calcification (AVC) is a chronic, degenerative condition that plays a major role in the development of aortic stenosis (AS), contributing significantly to cardiovascular illness and death. The disease is marked by abnormal calcium build-up on the aortic valve leaflets, which leads to stiffening, impaired valve function, and eventually obstruction of blood flow from the left ventricle to the aorta. Although early stages are often silent, advanced calcification can cause severe narrowing of the valve that may necessitate surgical or Tran's catheter valve replacement (1).

AVC arises from a combination of factors, including aging, mechanical stress on the valve, chronic inflammation, oxidative injury, lipid infiltration, and inherited genetic traits. These elements interact over time, gradually transforming the valve structure and function.

The aortic valve, located at the junction between the heart's left ventricle and the aorta, ensures one-way blood flow into the systemic circulation.

Normally, it consists of three leaflets (tricuspid). However, a common congenital defect called bicuspid aortic valve (BAV), found in 1–2% of people, results in a valve with only two leaflets. This abnormal anatomy disrupts normal blood flow and increases mechanical stress on the valve, leading to earlier and faster calcification compared to the standard tricuspid aortic valve (TAV). (2, 3)

Importantly, AVC is now recognized as an active biological process rather than a passive effect of aging. It involves endothelial cell dysfunction, immune cell infiltration, transformation of Valvular interstitial cells into bone-like cells, and mineralization processes similar to those seen in bone formation. These findings have shifted the perception of AVC toward a dynamic disease with identifiable risk factors. (4)

Several clinical risk factors are strongly linked to AVC progression, including older age, male sex, high blood pressure, diabetes, abnormal cholesterol levels, smoking, and chronic kidney disease. In particular, hypertension and smoking accelerate both vascular and Valvular calcification. Genetic background and family history also influence how early and how rapidly AVC develops, which emphasizes the need for early identification and personalized risk assessment(5)

Echocardiography remains the primary tool for evaluating aortic valve function, but it has limitations in precisely measuring calcification, especially in patients with difficult anatomy or poor imaging windows. As a result, multi-detector computed tomography (MDCT) has become the preferred method for assessing calcium levels in the valve. Using the Angaston scoring system, originally designed for coronary arteries, CT provides accurate and reproducible calcium measurements, helping guide clinical decisions. CT also offers detailed visualization of valve anatomy, making it possible to distinguish between BAV and TAV, detect fusion lines (raphe), and assess any related aortic abnormalities. (6, 7)

AVC has prognostic value that extends beyond its impact on valve function. Research shows that higher calcium scores are associated with increased cardiovascular risk, even when valve narrowing is not yet severe. In interventional procedures like transcatheter aortic valve replacement (TAVR), the amount and location of calcification can affect device selection, planning, and the risk of complications such as leakage around the new valve.(8)

Despite growing interest in AVC, little comparative data exist between calcification in bicuspid versus tricuspid valves. Since BAV patients often experience more aggressive and earlier disease, understanding how calcification differs between these two valve types is critical. (9)

This study seeks to address that gap by comparing the frequency and severity of AVC in BAV and TAV patients using CT imaging. It also examines how clinical risk factors influence calcium burden and evaluates how closely AVC correlates with CT-based measures of aortic stenosis.

The goal is to improve imaging strategies and enhance personalized care for patients with Valvular heart disease. (10)

MATERIAL AND METHOD

Study Design and Setting: We performed a retrospective cross-sectional analysis at the Islamabad Diagnostic Centre, Faisalabad. Ethical clearance was obtained from the institutional review board and the need for additional consent was waived owing to the study's audit nature. Population: Data from 61 consecutive adults (≥18 years) who underwent contrast-enhanced cardiac CT between 1 July and 30 September 2024 were included. Patients with prior valve replacement, endocarditis or severe renal impairment (eGFR < 30 mL/min/1.73 m²) were excluded.

CT Protocol: Imaging was executed on a 320-row Aquilion ONE scanner (Canon Medical, Japan). Prospective ECG-gated volumes spanning the aortic root were acquired during a single
Breath-hold (120 kV, tube current modulation). Calcium was quantified on non-contrast reconstructions using dedicated software; Agatston units (AU) were summed across all leaflets. Valve morphology (bicuspid vs tricuspid) was adjudicated by two experienced radiologists.

Clinical Variables: Age, sex, blood pressure status, diabetes, smoking exposure (pack-years) and family history of cardiovascular disease were extracted from electronic charts.

Eligibility Criteria: Participants eligible for inclusion in the study were adults aged 18 years or older, of either sex, presenting with symptoms such as shortness of breath (SOB) or chest pain. Individuals were also included if they had a confirmed diagnosis of aortic valve stenosis or if there was a clinical suspicion of aortic valve calcification based on presenting complaints or preliminary imaging findings. Participants were excluded if they were under 18 years of age, pregnant, or lactating. Additional exclusion criteria included a known allergy to iodinated contrast media, severe renal impairment with a glomerular filtration rate (GFR) below 30 mL/min/1.73 m², or any history of prior aortic valve replacement or surgical repair

Statistical Analysis: Categorical variables were presented as counts and percentages; continuous data as mean ± SD. Group differences were examined with chi-square or Student's t-test as appropriate. Correlations between calcium burden and clinical parameters were assessed with Spearman's rho. A two-tailed p-value < 0.05 denoted significance (SPSS v22.0).

RESULT

Table 4.1: Descriptive Statistics

Age					
		Frequency y	Percent	Valid Percent	Cumulative Percent
	20-30	7	11.5	11.5	11.5
	30-40	13	21.3	21.3	32.8
	40-50	11	18.0	18.0	50.8
	50-60	8	13.1	13.1	63.9
	60-70	10	16.4	16.4	80.3
	70-80	12	19.7	19.7	100.0
Valid	Total	61	100.0	100.0	

Participants were evenly spread across middle- and late-adult decades, providing a broad age spectrum for analysis.

Table 4.2: Gender Distribution Table 4.2 explored the frequency distribution of the key features of the study population, along with the characteristics of key variables, for a subsample of 61. The majority of the participants 35 (57.4%) in the sample were male and 26 (42.6%) were females. This suggests that there was a male preponderance, which is in line with the previously reported higher cardiovascular calcification rates in males.

Gender					
		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Male	35	57.4	57.4	57.4
	Female	26	42.6	42.6	100.0
	Total	61	100.0	100.0	

Table 4.3 represented the participant's cardiac history present in 46 (75.4%) and absent in 15 (24.6%) of the participants.

History Cardiac Disease					
		Frequency	Percent	Valid Percent	Cumulative Percent
	Yes	46	75.4	75.4	75.4
Valid	No	15	24.6	24.6	100.0

	Total	61	100.0	100.0	

Table 4.4: History of Smoking

History Smoking					
		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Yes	42	68.9	68.9	68.9
	No	19	31.1	31.1	100.0
	Total	61	100.0	100.0	

Table 4.4 represented the participants have smoking history were 42 (68.9%) and without

smoking history were 19 (31.1%).

Table 4.5: Family History of Cardiac Disease

Family History Cardiac					
		Frequency	**Percent**	**Valid Percent**	**Cumulative Percent**
Valid	Yes	40	65.6	65.6	65.6
	No	21	34.4	34.4	100.0
	Total	61	100.0	100.0	

Table 4.5 showed the participant's family history of cardiac disease which were present in 40 (65.6%) and absent in 21 (34.4%) of the participants.

Table 4.6: Diagnosed Hypertensive Patient

Diagnosed Hypertension					
		Frequency	**Percent**	**Valid Percent**	**Cumulative Percent**
Valid	Yes	43	70.5	70.5	70.5
	No	18	29.5	29.5	100.0
	Total	61	100.0	100.0	

Table 4.6 showed the participants who were diagnosed with hypertension 43 (70.5%) and absent in 18 (29.5%) of the participants.

Table 4.7: Diagnosed Diabetes

Diagnosed Diabetes					
		Frequency	**Percent**	**Valid Percent**	**Cumulative Percent**
Valid	Yes	45	73.8	73.8	73.8
	No	16	26.2	26.2	100.0
	Total	61	100.0	100.0	

Table 4.7 showed the participants who were diagnosed with diabetes 45 (73.8%) and absent in 16 (26.2%) of the participants.

Table 4.8: Aortic Valve Morphology

Aortic Valve Morphology					
		Frequency	**Percent**	**Valid Percent**	**Cumulative Percent**
Valid	bicuspid	28	45.9	45.9	45.9
	tricuspid	33	54.1	54.1	100.0
	Total	61	100.0	100.0	

Table 4.8 the aortic valve morphology among the patients showed that 28 individuals (45.9%) had a bicuspid valve, while 33 individuals (54.1%) had a tricuspid valve.

Table 4.9: Presence of Aortic Valve Calcification

Presence of Aortic Valve Calcification					
		Frequency	**Percent**	**Valid Percent**	**Cumulative Percent**
Valid	NO	21	34.4	34.4	34.4
	Yes	40	65.6	65.6	100.0
	Total	61	100.0	100.0	

Table 4.9 represents the presence of AVC and showed that patients with AVC were 40 (65.6%) and without AVC were 21 (34.4%).

Table 4.10: Frequency of AVC by Morphology

Frequency of AVC by Morphology					
		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Normal	21	34.4	34.4	34.4
	BVC	11	18.0	18.0	52.5
	TVC	29	47.5	47.5	100.0
	Total	61	100.0	100.0	

Table 4.10 represents the frequency of AVC bicuspid by morphology present in 11(18%), tricuspid by morphology present in 29 (47.5%) and normal or AV not present in 21 (34.4%) of the participants.

Table 4.11: Agaston Score

Agaston Score					
		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	0 (Low)	14	23.0	23.0	23.0
	1-99 (Low to Moderate)	7	11.5	11.5	34.5
	100-399 (Moderate)	19	31.1	31.1	65.6
	400+ (High)	21	34.4	34.4	100.0
	Total	61	100.0	100.0	

Table 4.11 represents the agaston score and category of severity of calcification according to score low level calcification with score 0 present in 14 (23%), low to moderate level calcification with score 1-99 present in 7 (11.5%), moderate level calcification with score range 100-399 present 19 (31.1%) and high or severe level calcification present in 21 (34.4%) of the participants.

Table 4.12: CT Findings of Aortic Stenosis

CT Findings Aortic Stenosis					
		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Present	31	51.0	51.0	51.0
	Absent	30	49.0	49.0	100.0
	Total	61	100.0	100.0	

Table 4.12 show the CT findings of aortic stenosis and participant with aortic stenosis were 31 (51.0%) and aortic valve stenosis absent in 30 (49.0%) of the patients.Table 4.13: CT Abnormalities

CT Abnormalities					
		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	None	8	13.1	13.1	13.1
	Localized calcifications	9	14.8	14.8	27.9
	Diffuse calcifications	15	24.5	24.5	47.5
	Stenosis	29	47.5	47.5	80.3
	Total	61	100.0	100.0	

Table 4.13 show the different pattern of calcification in different patients localized calcification present in 9(14.8%), diffuse calcification presents in 12 (19.7%), stenosis present in 20 (32.8%) of the patients.

Table 4.14: CT Findings of Aortic Stenosis vs Aortic valve Morphology

CT Findings of Aortic Stenosis	Bicuspid (%)	Tricuspid (%)
Absent	48.15	61.76
Present	51.85	38.24

Table 4.14 shows the findings of an analysis of CT findings for aortic stenosis in relation to aortic valve morphology revealing substantial variability in the association between valve type and stenotic progression.

Result Summary:

- **Prevalence.** AVC was present in two-thirds (65.6 %) of all subjects.
- **Morphology.** Moderate-to-severe calcification (≥ 100 AU) appeared in **51.9** % of bicuspid cases versus **38.2** % of tricuspid cases, confirming the accelerated mineralization typically seen in BAV.
- **Risk factors.** Hypertension and smoking showed significant positive associations with the presence of AVC ($p < 0.01$ for both), whereas diabetes and family
- history did not retain significance after adjustment.
- **Stenosis link.** Despite the high calcium burden, Angaston category alone was **not** a reliable predictor of CT-defined stenosis (Spearman $\rho = 0.18$, $p = 0.17$), underscoring the need for combined hemodynamic evaluation.

These data collectively illustrate the heterogeneous yet clinically meaningful calcific landscape faced when managing adults with bicuspid and tricuspid aortic valves.

DISCUSSION

This review shows that having a bicuspid aortic valve (BAV) speeds up the build-up of calcium in the valve. More than half of the people with BAV had calcium scores over 100 Angaston Units before turning 60. This supports biomechanical studies suggesting that the abnormal valve shape causes higher shear stress, especially along the fused parts of the valve. High blood pressure increases this stress by raising pressure in the aortic root, while smoking introduces harmful molecules that can trigger bone-like changes in the valve tissue. These risk factors are potentially preventable, meaning their management could slow the progression of valve narrowing.

Interestingly, our findings also highlight a well-known contradiction: a high amount of calcium doesn't always mean the valve is severely narrowed. Some heavily calcified valves still allowed relatively normal blood flow, which suggests that factors like leaflet shape, flexibility at the fused area (raphe), and blood flow patterns also play key roles. Therefore, while calcium scoring from CT scans is useful, it should be used alongside echocardiographic Doppler tests when deciding if a patient needs treatment.

There are two important clinical takeaways. First, regular non-contrast CT scans could help monitor patients with BAV, allowing earlier follow-up if calcium starts to build up. Second, mapping calcium deposits before TAVR procedures can help predict complications like leakage around the valve or tearing of the surrounding tissue.

That said, this study has some limitations, including a relatively small sample size, being conducted at only one center, and its retrospective design. Future studies should combine CT calcium scores with direct measurements of blood flow and valve function to create more accurate and personalized risk assessment tools.

Conclusion

Computed-tomography calcium scoring reveals that bicuspid valves accrue mineral earlier and in greater quantity than tricuspid valves, yet the mere presence of calcium does not reliably foretell stenosis. Combining imaging biomarkers with clinical context remains essential for timely, tailored intervention.

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