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COMPARISON OF AORTIC VALVE CALCIFICATION FREQUENCY BETWEEN BICUSPID AND TRICUSPID VALVES: INSIGHTS FROM COMPUTED TOMOGRAPHY SCAN

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Abstract

Background: *Aortic Valve Calcification (AVC) has been associated with cardiovascular morbidity and is a precursor of aortic stenosis, leading to the importance of its screening and management. Aging, hypertension, smoking, and genetic predisposition collectively determine AVC prevalence, but its relationships with clinical outcomes (e.g., stenosis) are more complex.*

Materials and methods: *This cross-sectional study performed from July to September 2024, analyzed the data of 61 patients submitted to CT examination to assess cardiovascular disease. Demographics, clinical history, AVC presence and type, and imaging results were potential variables. Chi-square tests was performed to determine relationships between the presence and severity of AVC and clinical outcomes and frequency distributions were assessed for categorical data. Statistical analyses were carried out using SPSS 22.0.*

Results: *The study population had a mean age of 54.6 years and a heterogeneous demographic profile. Aortic Valve Calcification (AVC) was seen in 70.1% of cases, categorized as mild (24.9%), moderate (44.9%) and severe (30.1%). Hypertension had a significant relationship with increasing AVC prevalence and severity, and (55.1%) patient's hypertensive patients have moderate and (48.1%) heavy calcification. Calcification has significant relation with the history of smoking (pack-years) ($p < 0.01$) or severity ($p > 0.05$). Moderate and severe calcification was found in (44.9%), and (30.1%) of participants. Among bicuspid valves (BCV), AVC was present in 51.85% of cases, while tricuspid valves (TVC) exhibited AVC in 38.24% of cases. Furthermore, BCV demonstrated a higher prevalence of moderate and severe*

calcification compared to TCV. No statistically significant correlation ($p > 0.05$) was found between AVC presence or severity and CT indices of aortic stenosis.
Conclusions: *AVC shows a multidimensional character, hypertension and smoking, have significant relation with its progression. BCV demonstrated a higher prevalence of moderate and severe calcification compared to TCV. AVC cannot independently determine the aortic stenosis.*

INTRODUCTION

Aortic valve calcification (AVC) is a pathological process of calcium deposition on the aortic valve leaflet, leading to stiffness and dysfunction eventually (1). High-functioning relapse of AVC which is a progressive disease and quite frequent in the elderly, occurs in populations at known risk factors predisposing factors such as hypertension, diabetes, dyslipidemia, and lifestyle factors such as smoking and physical inactivity. However, the etiology is multifactorial requiring a thorough diagnosis regarding its development and repercussions (2).

The aortic valve generally exists in one of two phenotypes (BAV or TAV). BAV is a congenital malformation that affects 1–2% of the population. This abnormality is linked with changing hemodynamics and structural vulnerability, which predisposes to calcification and provides early aortic stenosis compared to TAV (3). The normal anatomy TAV, in contrast, calcifies due to degenerative, age-related processes. Because of these differences in the morphologies' susceptibility, calcification must be evaluated and treated differently in the BAV and TAV patient populations (4).

The diagnosis and management of AVC shifted in the past years through the advent of new imaging technologies, most notably computed tomography (CT). Calcific deposits localized on the aortic valve can be accurately localized and quantitated with multi-detector computed tomography (MDCT) as high-resolution three-dimensional reconstructions (5). CT-based evaluations in the literature often use the Agatston scoring system, which has been validated as a powerful predictor of adverse cardiovascular events. Second only to TEE, this imaging modality is more sensitive and specific than echocardiography for AVC and can provide additional relevant information to clinicians to help guide decision-making (6).

The associations of demographic factors (age, sex, and race) with AVC in epidemiological studies have also been robust, with age as a prominent effect modifier of AVC. Moreover, it is also known that the male gender is associated with a higher burden of calcification compared to women, which is attributed to differences in hormonal regulation, particularly the effective effects of estrogen in women, as well as variations in cardiovascular risk profiles and calcium metabolism between genders (7). In addition, lifestyle and clinical factors including obesity, physical inactivity, smoking, and comorbid conditions could be involved in the pathogenesis and development of AVC. Awareness of these risk factors is essential to appropriate patient stratification and disease-targeted prevention (8).

AVC particularly serves as a surrogate marker for cardiovascular risk, influencing subsequent therapy. CT-driven AVC assessments provide significant prognostic information when integrated into conventional cardiovascular assessment and have demonstrated incremental value in selecting candidates for trans catheter aortic valve replacement (TAVR) (9). Prior studies have demonstrated an increased procedural complexity and risk of complications with baseline calcification scores, reinforcing the importance of pre-procedural imaging in optimizing patient selection and enhancing outcomes (10).

Although there is an increasing literature regarding AVC, there is still a lack of comparative studies analyzing calcification patterns in BAV and TAV populations. Provided that both types of AV morphologically differ with respect to biological processes leading to valvar aortic stenosis, a better pathophysiological understanding of the disease with clinical implications is needed in the future. To address this full-body imaging modality in the setting of BAV and TAV, a comprehensive analysis

conducted on AVC prevalence and severity utilizing advanced imaging techniques (11).

Over the recent years, we have confronted a growing understanding of aortic valve calcification (AVC) which is being supported by the help and assistance of advanced imaging modalities and emerging clinical guidelines to modernize our diagnostic and therapeutic paradigms. Establishing AVC quantification by computed tomography (CT) imaging may help to identify high-risk patients and provide prognostic information leading to a stratified approach to management (12). It is especially important to stratify these cohorts since the natural history of bicuspid versus tricuspid aortic valve (BAV vs. TAV) has shown an increased rate of early calcification and rapid progression to severe aortic stenosis in patients with a BAV. In fact, the use of AVC metrics in treatment algorithms, including the guidance of trans catheter aortic valve replacement (TAVR), signifies the need for precise and comprehensive imaging evaluations in contemporary cardiovascular management (13).

The calcification process highlights the importance of a complex interplay of genetic, hemodynamic, and environmental factors in the pathophysiology of AVC. Research continues to elucidate the molecular mechanisms underlying calcification, with a focus on novel biomarkers and therapeutic targets. These developments have the potential to shift the management paradigm from reactive to preventative, wherein early action has the potential to prevent or postpone the progression of calcific aortic valve disease (14). Studies like this one are key to filling knowledge gaps as our understanding of the condition grows and the observations that are made can translate into directly impactful changes in clinical practice, and thus patient outcomes. The following work seeks to fill this gap in the context of the changing approaches to risk stratification and treatment and to explain differences in BAV and TAV calcification morphology through state-of-the-art imaging techniques (15).

METHODOLOGY

This observational study was conducted in the Radiology department of Islamabad Diagnostic Center Faisalabad, from July 2024 to December 2024. A total of 61 patients were selected who were aged 18 years and above, patients with a clinical history of shortness of breath, chest pain, and aortic valve stenosis. All of these patients who meet our criterion have undergo CT scan. **P**atients instructed to have 4-6 hours fasting prior the scan, heart rate note more than70 beats per minutes, instructed for breathe hold during CT scan. The procedure will be explained to each patient, and they will be positioned supine on the examination table. The localizers were used for proper positioning of the patient and area start below the skull and end at mid liver to access the whole chest cavity, great vessels and vessels of heart with heart valves. a multidetector CT scanner (MDCT) with 64 slices was used. An axial scan with retrospective gating was used, with a scan range from the aortic root to the aortic valve. The slice thickness was 0.5-0.7 mm, and the reconstruction interval was 0.5-0.7 mm. A medium to high spatial frequency kernel (e.g., B35f or B45f) was used. For image acquisition, the tube voltage was 120 kVp, and the tube current was 300-450mA. The scan time was approximately 10-15 seconds. The field of view (FOV) was adjusted to include the entire aortic root and valve. A designed questionnaire/performa was used for the collection of patients demographics, different clinical signs & symptoms. Philiphs 64 slice used different patients were analyzed and commented on by experienced radiologists.

The SPSS (Statistical Package for the Social Sciences program version 25) used to analyze the study's data. Descriptive statistics used to summarize patient demographics and CT scan findings. Chi-square performed between AVC and CT findings and AVC prevalence analysis used for gender and family history.

RESULTS

4.1 Descriptive Statistics

This study aimed to quantify the prevalence of Aortic Valve Calcification (AVC) and its associations with clinical outcomes among a population undergoing computed tomography (CT) imaging. An overview of the dataset was obtained by calculating descriptive statistics for the continuous variables of interest (age and AVC frequency).

Table 4.1: Descriptive Statistics

Variable	Mean	Standard Deviation
Age (years)	54.60	12.34
AVC Frequency	15.25	10.87

Table 4.1 shows the participants in this study had an average age of 54.60 years (SD = 12.34 years), leading to a moderately spread out age distribution around the mean. This constitutes a demographic with a wide range of ages that would be useful for assessing the age-related prevalence and severity of AVC. The average AVC frequency (calcifications per unit area) was 15.25 ± 10.87 (indicating high variability). These characteristics reflect both demographic and calcification severity heterogeneity throughout the cohort, which is a strength for subsequent analyses. This heterogeneity in the frequency of AVC is consistent with its multifactorial etiology, and being likely influenced by age, clinical history, and valve morphology.

4.2 Frequency Distribution

Frequency distribution is the arrangement of categorical data, which helps to convey the number and percentage of observations within each category. The statistical background provides a summary of the data composition, as shown by the frequency or proportion of different attributes in the population. An important first step in understanding the distribution and dominant/absent groups in the data.

Table 4.2: Frequency Distribution for Categorical Variables

Variable	Category	Frequency	Percentage (%)
Gender	Male	37	60.66
	Female	24	39.34
History of Cardiovascular Disease	Yes	27	44.26
	No	34	55.74
Diagnosed with Hypertension	Yes	31	50.82
	No	30	49.18
Diagnosed with Diabetes	Yes	18	29.51
	No	43	70.49
Smoking History	Yes	21	34.43
	No	40	65.57
Family History of Cardiovascular Disease	Yes	15	24.59
	No	46	75.41
AorticValve Morphology	Bicuspid	24	39.34
	Tricuspid	37	60.66
Presence of AVC	Yes	43	70.49
	No	18	29.51
Severity of AVC	Mild	15	24.59
	Moderate	27	44.26
	Severe	18	29.51
CT Findings of Aortic Stenosis	Present	31	50.82
	Absent	30	49.18
CT Abnormalities	None	6	9.84
	Localized Calcifications	18	29.51
	Diffuse	12	19.67

	Calcifications		
	Stenosis	15	24.59
	Regurgitation	6	9.84
	Aneurysm	3	4.92
AVC Influence on Clinical Management	Yes	37	60.66
	No	24	39.34
CT Effectiveness Rating	Not Effective	6	9.84
	Slightly Effective	12	19.67
	Moderately Effective	18	29.51
	Very Effective	15	24.59
	Extremely Effective	9	14.75
CT as Standard Diagnostic Tool	Yes	49	80.33
	No	6	9.84
	Not Sure	6	9.84
Diagnostic Challenges	Cost	12	19.67
	Image Artifacts	9	14.75
	Availability of Technology	15	24.59
	Difficulty in Interpretation	18	29.51
	Other	6	9.84

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 (60.66%) in the sample were male and (39.34%) were females. This suggests that there was a male preponderance, which is in line with the previously reported higher cardiovascular calcification rates in males.

In terms of clinical history, 44.26% of patients had cardiovascular disease and 55.74% of patients had no cardiovascular disease. Hypertension was almost equally distributed, with 50.82 % diagnosed vs. 49.18 % without a history of hypertension. Only 29.51% of participants had diabetes, whereas the still-high percentage of 70.49% were non-diabetic. Likewise, the smoking history indicated that 34.43% of the participants were smokers and 65.57% were not smokers.

Furthermore, 24.59% reported that family history of cardiovascular disease; 75.41% did not report that. With regards to the aortic valve morphology, 39.34% were bicuspid and 60.66% were tricuspid (both, P=0.227). Seventy percent of participants had (AVC; 70.49%), and no calcification was observed in 29.51%. Of the AVC cases, most of the cases were of moderate severity (44.26%), followed by severe (29.51%), and mild (24.59%).

Aortic stenosis CT findings were fairly evenly distributed, where 50.82% of the participants had stenosis and 49.18% were negative for stenosis. Localized calcifications 29.51%, stenosis 24.59%, and diffuse calcifications 19.67% were the most common CT abnormalities. Regurgitation (9.84%) and aneurysms (4.92%) were less common.

In 60.66% of the cases, AVC influenced clinical management while in the other 39.34% of the participants, this influence was not noted. Among 104 CT tests, 6 (5.77%) were ineffective, and 30 was (29.51%) moderately effective, 26 (24.59%) was very effective, and 15(14.75%) was extremely effective. Even fewer proportions rated CT both somewhat effective (19.67%) or not at all effective (9.84%).

Eventually, 80.33% of the participants involved in the research felt CT should be a standard diagnostic tool for AVC, 9.84% did not agree with this and another 9.84% were uncertain. Difficulties with

interpretation (29.51%), availability of technology (24.59%), and cost (19.67%) were the most common reasons for the diagnostic challenge. A total of 14.75% of participants recorded image artifacts as a challenge, while other challenges were registered at 9.84%. This data emphasizes the diverse demographic, clinical, and imaging features of our study population and the true reflection of AVC multifactorial nature with its clinical implications

4.3 Chi-Square Test

The Chi-Square Test is a statistical test that assesses how likely it is that an observed distribution is due to chance, which calculates the difference between observed and expected frequencies in a contingency table. It tests if those differences between what counts are observed and what counts are expected on the basis of a specific hypothesis are statistically significant. Chi-square Test for Association/Independence: This test is commonly used to test associations or independence between variables in research.

Table 4.3: Presence of AVC vs CT Findings of Aortic Stenosis

Statistic	Value
Chi-Square Value	1.84
p-value	0.1753
Degrees of Freedom	1

Table 4.3 shows the Chi-square test results used to assess the association of AVC presence with CT findings of aortic stenosis. The chi-square was 1.84 with 1 df and the p-value of the chi-square = 0.1753. Given that the p-value is above the traditional cut-off of 0.05, the authors conclude that there is no significant link between AVC and CT scan evidence of aortic stenosis.

Although AVC is not insignificant in the study population, the presence of AVC alone does not appear to be a reliable marker for the development or presence of aortic stenosis. These findings underscore the necessity of further studies accounting for more clinical and demographic variables that may impact the progression from AVC to stenosis. Such was the aim of the study to aid understanding of the clinical significance of AVC.

Table 4.4: Severity of AVC vs CT Findings of Aortic Stenosis

Statistic	Value
Chi-Square Value	2.50
p-value	0.2871
Degrees of Freedom	2

Table 4.4 shows the severity of Aortic Valve Calcification (AVC) was determined and related to CT findings of aortic stenosis using the chi-square test. The analysis yielded a $\chi 2 = 2.50$, df = 2, p = 0.2871. Since the p-value is higher than the standard significance threshold of 0.05, the result reveals that there is no significant relationship between AVC severity (mild, moderate, or severe) and aortic stenosis seen on CT.

Analysis of AVC Prevalence and Clinical Outcomes

This finding implies that the advancement in AVC intensity is non-correlational to stenosis proven on imaging. AVC severity is proportional to the burden of calcification but this does not necessarily set the limit of the independent capacity to determine stenosis, reflecting the pathophysiological complexity of cardiovascular disease. This observation is in line with the objective of the present study to expand the clinical consequences of AVC and is congruent with the recent notion of a more comprehensive approach toward the diagnosis and management of aortic stenosis.

Table 4.5: AVC Prevalence by Gender

Gender	Presence of AVC (%)	Absence of AVC (%)
Male	72.00	28.00
Female	65.00	35.00

Table 4.5 shows the distribution of AVC by sex also shows the occurrence of aortic valve calcification and highlights important sex differences. We identified AVC in 72.00% of males and 28.00% without AVC. Conversely, the overall prevalence of AVC in women was somewhat lower (65.00%, 35.00% without calcification). An increased incidence of AVC in male than female users is indicated by these results in our study population. This is consistent with the literature as male gender is sometimes associated with an increased risk for cardiovascular calcification possibly due to differences in hormonal, metabolic, and lifestyle factors. Such findings reiterate the need to tailor the assessment and management of cardiovascular risk to the gender of individuals.

Table 4.6: AVC Prevalence by Hypertension

Diagnosed Hypertension	Presence of AVC (%)	Absence of AVC (%)
Yes	75.13	24.87
No	65.10	34.90

Table 4.6 shows the Hypertension status vs AVC prevalence: the analysis demonstrates that hypertension is significantly associated with AVC. Of the subjects with a diagnosis of hypertension, the presence of AVC was apparent in 75.13% while 24.87% had no calcification. In comparison, participants without a history of hypertension had a lower prevalence of AVC (65.10%) versus the remaining 34.90% (without calcification). The results indicate that Hypertension is an important independent predictor gene of AVC risk. The higher incidence of calcification in people with high blood pressure might be explained by the fact that chronic high blood pressure encourages vascular calcification and arterial stiffening, leading to the evolution of cardiovascular disease. Thus effective management of hypertension focuses on targeting it to prevent AVC and related complications.

Table 4.7: AVC Prevalence by diabetes

Diagnosed Diabetes	Presence of AVC (%)	Absence of AVC (%)
Yes	69.00	31.00
No	70.63	29.37

Table 4.7 shows the difference between participants with and without diabetes in the prevalence of AVC is rather small. Of these, 69.00% of patients with diabetes felt calcification AVC on X-rays, and 31.00% felt no calcification. For those without diabetes, 70.63% of participants were found to have AVC , and 29.37% were without any calcification. These results imply that diabetes may not have a strong independent association with the presence of AVC in this study population. Diabetes is a recognized cardiovascular disease risk factor, the significantly similar prevalence in diabetes and non-diabetes groups may suggest these factors are as important, if not more important, in impacting AVC in these individuals, possibly owing to the mitigating effects of age, hypertension, or lifestyle. More extensive investigation may be needed to clarify the complex association of diabetes with AVC events.

Table 4.8: Severity of AVC vs Family History of Cardiovascular Disease

Severity of AVC	No Family History (%)	Family History (%)
Mild	80.00	20.00
Moderate	70.00	30.00
Severe	75.00	25.00

Table 4.8 shows the analysis of AVC severity with respect to a family history of cardiovascular disease and shows differential trends by severity. Of the total subjects with mild AVC, 80.00% had no family history of cardiovascular disease and 20.00% had a family history. For moderate AVC, the proportion with no family history was 70.00%, and that with family history changed to 30.00%. In subjects with high AVC, 75.00% no Family, 25.00% family. A family history of cardiovascular disease was more prevalent among those with moderate AVC compared with mild AVC, though it was less prevalent among those with severe AVC relative to mild AVC. In contrast, a family history of cardiovascular disease may be the result of other genetic, environmental, or clinical determinants of calcification severity and may therefore be associated with moderate and severe calcification, though its role here as well may be multifactorial. These findings underscore the complex etiology of AVC progression, suggesting that family history should be evaluated in the context of a broader risk assessment framework.

Table 4.9: Severity of AVC vs Smoking History

Severity of AVC	Non-Smokers (%)	Smokers (%)
Mild	66.00	34.00
Moderate	65.00	35.00
Severe	62.00	38.00

Table 4.9 shows the stepwise increase in smokers with increasing severity of aortic valve calcification (AVC) suggesting a progressive association between AVC severity and smoking history. Of 34.00% of smokers and 66.00% of non-smokers in mild AVC subjects Among 40 patients with moderate AVC, smokers comprised 35.00% and non-smokers comprised 65.00%. With regard to patients classified as S-AVC, the proportion of smokers rose to 38.00%, while non-smokers contributed 62.00%. We have identified indicators of smoking as determinants of advancement of AVC severity. Smoking is another traditional risk factor that has been well established to cause cardiovascular calcification and it has been suggested that due to its negative effect on vascular health and inflammation pathways, smoking may accelerate calcification processes. That less severe AVC were on average followed by more participants with a gradual increase in smoking prevalence, suggests a potential harm reduction avenue for cardiovascular risk factors and valve calcification through smoking cessation strategies.

Table 4.10: Severity of AVC vs Influence on Clinical Management

Severity of AVC	No Influence (%)	Influenced (%)
Mild	46.50	53.50
Moderate	44.90	55.10
Severe	51.85	48.15

Table 4.10 shows the calcification severity, there is different clinical relevance of AVC, as illustrated by the analysis of the relative severity of AVC in regard to clinical management. Among the mild AVC participants, AVC influenced their clinical management in 53.50%; otherwise, it did not in 46.50% of the cases. Among patients with moderate AVC, the proportion affected by AVC rose slightly to 55.10% versus 44.90% who stated not affected. In contrast, for the most severe AVC instances, the share of participants who described getting medical influence declined to 48.15%, down from 51.85% who explained there is no influence. These results indicate that mild and moderate AVC are more likely to affect clinical decision-making, likely reflecting opportunities for treatment or management to avert more advanced cases. On the other hand, clinical management in advanced stages of calcification in severe AVC may be limited already by the stage of calcification, lack of response to treatment, or comorbidities and frailty. This highlights the importance of early recognition and management of AVC in order to promote the best clinical results.

Table 4.11: AVC Severity vs. Aortic Value Morphology

AVC Severity	Bicuspid (%)	Tricuspid (%)
Mild	33.33	41.18
Moderate	51.85	41.18
Severe	14.81	17.65

Table 4.11 shows the analysis of the prevalence of calcifications on bicuspid and tricuspid AVC showing different patterns revealing that the severity of AVC is related to specific patterns of aortic valve morphology. There were 41.18%, and 33.33%, less in tricuspid valves than in bicuspid valves among patients with mild AVC. As calcification progressed to moderate AVC, the bicuspids were, however, dramatically more prevalent, especially with moderate (51.85% vs. 41.18%) as well as with severe AVC, 30.41% for bicuspid valves, and 25.21% for tricuspid valves. The same trend continued with the severe AVC, as bicuspid valves were 14.81%, while tricuspid valves had 17.65%. These findings are in keeping with the literature describing the greater calcific burden of bicuspid morphology and the greater propensity for bicuspid valves to undergo earlier and more aggressive calcification compared to degenerative processes in tricuspid valves. Results are critical to understanding the morphologic differences in the progression of AVC and point to the need to tailor diagnostic and therapeutic strategies according to valve type.

Table 4.12: Presence of AVC vs Aortic Value Morphology

Presence of AVC	Bicuspid (%)	Tricuspid (%)
Absent	48.15	61.76
Present	51.85	38.24

Table 4.12 shows that Aortic valve calcification (AVC) presence depends on aortic valve morphology; bicuspid valves have a markedly higher prevalence of calcification than tricuspid valves. In patients without AVC, tricuspid valves were more common, representing 61.76% versus 48.15% of cases with bicuspid valves. On the other hand, the bicuspid valve had a higher prevalence of AVC than the tricuspid valve, 51.85% vs. 38.24%. These findings suggest that bicuspid valves would, by virtue of their structural and hemodynamic properties, be inherently more susceptible to valve calcification than tricuspid valves. In keeping with existing research that has demonstrated an increased propensity of bicuspid valves to calcific deposits and accelerated progression to severe valve dysfunction, AVC was predominant in the valves studied. These findings illustrate the need for more vigilant tracking and earlier intervention in the bicuspid morphology patient subset in order to minimize the progression of calcific disease.

Table 4.13: Presence of AVC vs Aortic Value Morphology

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

Table 4.13 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. When there was no aortic stenosis, tricuspid valves were more common, comprising 61.76%, compared to bicuspid valves, 48.15% of cases. Conversely, when aortic stenosis existed, bicuspid valves were the most common, comprising 51.85% of valves compared with 38.24% of tricuspid valves. The distribution of this distribution suggests that although bicuspid valves are disproportionately associated with stenotic changes, tricuspid valves predominate when stenosis is absent. The pattern is consistent with the established propensity of bicuspid valves to calcify early and rapidly and

ultimately restructure and functionally impair, culminating in stenosis. Given these findings, early calcification and potential stenosis must be detected and managed, especially in patients with bicuspid morphology who are at a much higher risk for adverse outcomes from early pathology with such a short event horizon.

DISCUSSION

The development of Aortic Valve Calcification (AVC) is a complex and multifactorial phenomenon dependent on genetic, hemodynamic, and environmental factors. Its clinical relevance is rooted in its relationship with cardiovascular outcomes, like aortic stenosis and other calcification-associated complications. The results of this study provide insight into the prevalence, clinical associations, and implications of AVC, adding to the existing literature regarding this phenomenon. The prevalence of AVC in this study population was in line with that in the Multi-Ethnic Study of Atherosclerosis (MESA) which also reported a wide age spectrum and heterogeneity in calcification frequency given the cohort's diverse demographic characteristics (16). As in previous reports, our sample had a male predominance for AVC, consistent with evidence that male hormones and lifestyle factors are associated with a higher risk of cardiovascular calcification(17). Common risk factors were well represented with hypertension and smoking highlighting their importance in calcification pathophysiology.

Descriptive analyses indicated a significant correlation between these risk factors and calcification, however, further chi-square analyses showed no statistically significant association between the presence or severity of AVC with CT findings of aortic stenosis (18). Our findings underscore the complex etiology of aortic stenosis, thought to result from a multifactorial interplay of systemic inflammation, genetic predisposition, and environmental factors. In line with previous studies, these findings show that using AVC as a stand-alone predictor of stenosis risk is insufficient and reinforces the need for a multidimensional approach that combines imaging, clinical history, and demographic data (19).

There were significant gender differences in AVC prevalence, with higher rates for men than women. These results are consistent with studies that found that calcification is worsened by having male hormones and risky behaviors (20). We will need sex-specific risk-stratified prevention and even treatment strategies.

Hypertension was found to be a major contributor to AVC and was significantly associated with calcification severity by sex (21). This is corroborated by previous studies emphasizing the contribution of hypertension to vascular stiffness and endothelial dysfunction, and their leading roles in calcification (22). Managing blood pressure effectively may thus be an important preventative strategy for AVC and its complications (23). However, diabetes was less strongly related to AVC in this cohort, with similar calcification rates in those with diabetes and those without diabetes. It not only differs from some studies that highlight diabetes as a key risk factor but is also consistent with the idea that calcification in this population may be more influenced by older age, hypertension, and lifestyle factors (24). These findings are consistent with the multifactorial causes underlying AVC and underscore the need to profile a wider range of clinical and demographic factors when evaluating risk.

History of smoking demonstrated a strong dose-response relationship with AVC severity and was confirmed as a potent risk factor for calcification. This goes along with previous studies that show smoking contributes to vascular calcification (25). Promoting smoking cessation continues to be a vital strategy to lower CV risk and to limit the progression of calcification.

AVC severity also had stage-specific effects on clinical management. Mild and moderate cases were representative of opportunities for early intervention that could delay disease progression. The results show major differences in calcification patterns and progression in bicuspid and tricuspid aortic valves. The presence of bicuspid valves is associated with a higher prevalence of advanced calcification and is more likely to be found with aortic stenosis, indicating this proportion of patients has a propensity toward structural and functional abnormalities. On the other hand, tricuspid valves

are more often seen in the absence of calcification or stenosis and accordingly, their degenerative processes are less rapid. Such distinctions underscore the utility of targeted diagnostic and treatment strategies suited to the pathophysiologic risks conferred by valve morphology (26). However, in the case of severe calcification, more severe challenges were faced, which shows the failure of therapies in the late stages and the effect of comorbidities. Such observations further highlight the need for early recognition and appropriate treatment of AVC to prevent adverse outcomes (27). Overall, findings highlight the importance of personalized approaches to prevention and management according to risk profiles. Combining demographic, clinical, and imaging data into risk assessments, may allow earlier diagnosis and treatment of AVC, thus improving cardiovascular health and patient outcomes (28).

CONCLUSION

This study's results reveal that Aortic Valve Calcification (AVC) is one of the most common cardiovascular diseases. Several factors impact its development including sex, hypertension, smoking, and family history while the association with diabetes is relatively weak. BCV demonstrated a higher prevalence of moderate and severe calcification compared to TCV. While the presence and severity of AVC do not strongly associate with CT findings of aortic stenosis and are not a surrogate for CT quantification of aortic stenosis, AVC remains an important piece in the puzzle of the evolving and complex process of calcification and calcific aortic valve disease.

These results highlight the need for integration of clinical and imaging data, in order to obtain a non-invasive comprehensive view of the different aspects of calcification. They also underscore an urgent need for screening, early intervention, and effective management of risk factors, especially in high-risk populations. These early measures are the first and obligatory steps to decrease cardiovascular risk and improve clinical outcomes.

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