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Challenges in Predicting Aortic Mechanical Valve Thrombosis: Evaluation of the CHA_2DS_2-VASc Score in a Clinical Cohort

Kamran Mohammadi

Assistant Professor of Cardiology, Department of Cardiology, School of Medicine, Cardiovascular Research Center, Tabriz University of Medical Sciences, Tabriz, Iran

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A B S T R A C T

Introduction: Mechanical aortic valve replacement requires lifelong anticoagulation, yet prosthetic valve thrombosis (PVT) can occur even with therapeutic INR levels, suggesting additional mechanisms beyond standard risk factors. This study aimed to determine whether the CHA_2DS_2-VASc score independently predicts PVT in mechanical aortic valve recipients, providing insight into whether classical thromboembolic predictors apply to this distinct clinical condition.

Material and methods: This case control study was conducted at Shahid Madani Heart Center, Tabriz, Iran, between 2017 and 2021. Using a census sampling method, 100 patients with mechanical mitral valve replacement were enrolled. Clinical, echocardiographic, and anticoagulation data were retrospectively collected to compare patients with confirmed prosthetic valve thrombosis and matched controls without thrombosis.

Results: After excluding patients with subtherapeutic anticoagulation, 22 patients with prosthetic valve thrombosis and 78 controls were analyzed. Baseline demographic, clinical, and anticoagulation parameters were comparable between groups, with no significant differences observed. The mean CHA_2DS_2-VASc score was numerically higher in the thrombosis group but did not differ significantly between groups (p=0.23).

Conclusion: In this cohort of patients with mechanical prosthetic valves who maintained therapeutic anticoagulation, traditional clinical and demographic factors were not associated with the development of prosthetic valve thrombosis.

Introduction

Mechanical aortic valve replacement remains a definitive therapeutic option for patients with severe aortic valve disease who require long-term durability and structural reliability. Despite substantial advances in prosthetic valve engineering and perioperative management, mechanical valves are intrinsically chromogenic and necessitate lifelong anticoagulation therapy. Prosthetic valve thrombosis (PVT), although less frequent in the aortic position compared with the mitral valve, represents a serious and potentially catastrophic complication that may lead to acute valve obstruction, systemic embolization, heart failure, or sudden death.

The clinical burden of PVT underscores the importance of accurately identifying patients at increased thrombotic risk, yet effective prediction remains a persistent challenge in contemporary cardiovascular practice. (1)

Long-term anticoagulation with vitamin K antagonists, most commonly warfarin, constitutes the cornerstone of thrombosis prevention in patients with mechanical heart valves. Anticoagulation intensity is routinely monitored using the international normalized ratio (INR), with guideline-recommended target ranges tailored to valve position and patient-specific risk factors.

Corresponding Author: **Kamran Mohammadi (Email: Mohammadikamran706@gmail.com - ORCID: 0000-0002-1589-5359)*

For most mechanical aortic valves, a target INR between 2.0 and 3.0 is considered sufficient. However, real-world anticoagulation control is often suboptimal due to dietary variability, drug interactions, genetic polymorphisms affecting warfarin metabolism, and inconsistent monitoring. Importantly, prosthetic valve thrombosis has been documented even among patients with apparently therapeutic INR levels, highlighting the limitations of INR as a sole surrogate for thrombotic risk. (2)

The pathophysiology of thrombosis in mechanical the aortic position compared with the mitral valve, represents a serious and potentially catastrophic complication that may lead to acute valve obstruction, systemic embolization, heart failure, or sudden death. The clinical burden of PVT underscores the importance of accurately identifying patients at increased thrombotic risk, yet effective prediction remains a persistent challenge in contemporary cardiovascular practice. Long-term anticoagulation with vitamin K antagonists, most commonly warfarin, constitutes the cornerstone of thrombosis prevention in patients with mechanical heart valves. Anticoagulation intensity is routinely monitored using the international normalized ratio (INR), with guideline-recommended target ranges tailored to valve position and patient-specific risk factors. For most mechanical aortic valves, a target INR between 2.0 and 3.0 is considered sufficient. However, real-world anticoagulation control is often suboptimal due to dietary variability, drug interactions, genetic polymorphisms affecting warfarin metabolism, and inconsistent monitoring. Importantly, prosthetic valve thrombosis has been documented even among patients with apparently therapeutic INR levels, highlighting the limitations of INR as a sole surrogate for thrombotic risk. The pathophysiology of thrombosis in mechanical aortic valves is fundamentally distinct from that observed in native cardiac structures or atrial fibrillation. Thrombus formation in this setting is driven by direct blood contact with non-endothelial zed artificial surfaces, abnormal shear stress, flow turbulence, and localized areas of flow stagnation, particularly near hinge mechanisms. These factors promote platelet activation, fibrin deposition, and local coagulation cascade activation independent of systemic hypercoagulable states. Consequently, valve-specific mechanical and hemodynamic determinants may play a more dominant role in PVT development than traditional demographic or clinical risk factors. (3)

In contrast, thromboembolic risk prediction in atrial fibrillation has been successfully standardized through the use of the CHA_2DS_2-VASc score. This widely validated clinical tool incorporates congestive heart failure, hypertension, age, diabetes mellitus, prior stroke or transient ischemic attack, vascular disease, and female sex to estimate the risk of systemic embolism. Its simplicity and strong prognostic performance have led to widespread adoption in routine clinical practice. Given its success in atrial fibrillation, the CHA_2DS_2-VASc score has been increasingly explored in other thrombotic conditions, including patients with prosthetic heart valves, despite limited pathophysiological justification for such extrapolation. (4)

Applying the CHA_2DS_2-VASc score to patients with mechanical aortic valves assumes that systemic cardiovascular comorbidities exert a similar influence on thrombus formation across fundamentally different biological environments. However, bus formation in this setting is driven by direct blood contact with non-endothelial zed artificial surfaces, abnormal shear stress, flow turbulence, and localized areas of flow stagnation, particularly near hinge mechanisms. These factors promote platelet activation, fibrin deposition, and local coagulation cascade activation independent of systemic hypercoagulable states. Consequently, valve-specific mechanical and hemodynamic determinants may play a more dominant role in PVT development than traditional demographic or clinical risk factors. In contrast, thromboembolic risk prediction in atrial fibrillation has been successfully standardized through the use of the CHA_2DS_2-VASc score. This widely validated clinical tool incorporates congestive heart failure, hypertension, age, diabetes mellitus, prior stroke or transient ischemic attack, vascular disease, and female sex to estimate the risk of systemic embolism. Its simplicity and strong prognostic performance have led to widespread adoption in routine clinical practice. Given its success in atrial fibrillation, the CHA_2DS_2-VASc score has been increasingly explored in other thrombotic conditions, including patients with prosthetic heart valves, despite limited pathophysiological justification for such extrapolation. Applying the CHA_2DS_2-VASc score to patients with mechanical aortic valves assumes that systemic cardiovascular comorbidities exert a similar influence on thrombus formation across fundamentally different biological environments. However, while atrial fibrillation–related thrombosis is primarily mediated by blood stasis and endothelial dysfunction within the left atrium, prosthetic valve thrombosis arises from localized interactions between circulating blood elements and an artificial surface under non-physiological flow conditions. As a result, the relative contribution ofbus formation in this setting is driven by direct blood contact with non-endothelial zed artificial surfaces, abnormal shear stress, flow turbulence, and localized areas of flow stagnation, particularly near hinge mechanisms. These factors promote platelet activation, fibrin deposition, and local coagulation cascade activation independent of systemic hypercoagulable states. Consequently,

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The aortic valve position introduces additional complexity due to its unique hemodynamic environment. High transvalvular flow velocities reduce global blood stasis but generate substantial shear stress, which can paradoxically enhance platelet activation and von Willebrand factor degradation. Furthermore, micro-regions of low shear and recirculation near valve hinges may serve as niduses for thrombus formation despite overall favorable flow conditions. These nuanced flow characteristics are not captured by conventional clinical risk scores, further questioning the relevance of CHA_2DS_2-VASc in predicting aortic mechanical valve thrombosis. (7)

Existing evidence evaluating the association between CHA_2DS_2-VASc score and prosthetic valve thrombosis is limited and inconsistent. Most available studies have focused on composite thromboembolic outcomes rather than confirmed valve thrombosis and frequently include heterogeneous valve types and positions. In several analyses, any apparent association between higher CHA_2DS_2-VASc scores and thromboembolic events diminishes after adjustment for anticoagulation intensity or the presence of atrial fibrillation. These findings suggest that CHA_2DS_2-VASc may reflect general vascular risk rather than valve-specific chromogenic potential. (9)

From a clinical perspective, predicting prosthetic valve thrombosis is further complicated by the dynamic nature of anticoagulation control. Transient periods of sub therapeutic INR, even if brief, may substantially increase thrombotic risk, while inflammatory states, infections, renal dysfunction, or hormonal changes can transiently alter coagulation age, hypertension, diabetes, and sex to thrombosis risk may be attenuated or obscured by the overwhelming pro-thrombotic stimulus of the mechanical prosthesis itself. (10)

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From a clinical perspective, predicting prosthetic valve thrombosis is further complicated by the dynamic nature of anticoagulation control. Transient periods of sub therapeutic INR, even if brief, may substantially increase thrombotic risk, while inflammatory states, infections, renal dysfunction, or hormonal changes can transiently alter coagulation balance. Static clinical scores fail to incorporate these temporal fluctuations, limiting their predictive accuracy. Consequently, reliance on simplified scoring systems may lead to false reassurance or unnecessary intensification of therapy in mechanical valve recipients. (13)

Despite these limitations, the CHA_2DS_2-VASc score continues to attract interest because of its familiarity and ease of use. Clinicians often seek practical tools that can be readily applied in busy clinical settings,

and the concept of a universal thromboembolic risk score is appealing. However, emerging data increasingly suggest that mechanical valve thrombosis represents a distinct clinical entity requiring disease-specific risk assessment strategies rather than adaptation of atrial fibrillation–based models. (14)

Patients undergoing mechanical aortic valve replacement represent a unique population characterized by relatively younger age, fewer systemic comorbidities, and prolonged exposure to anticoagulation therapy. Their long-term outcomes depend not only on achieving target INR values but also on maintaining stable anticoagulation over time. Variability in INR control, rather than absolute INR values, has been increasingly recognized as a critical determinant of thrombotic and bleeding events. Risk stratification tools that fail to account for this longitudinal dimension provide an incomplete assessment of true thrombotic vulnerability. (15)

Clarifying the role of CHA_2DS_2-VASc in this context carries important implications for the future of personalized valve care. Demonstrating limited or absent predictive value would support the development of valve-specific risk models incorporating prosthesis design, flow dynamics, anticoagulation quality metrics such as time in therapeutic range, and emerging biomarkers of coagulation or inflammation. Such approaches align with the broader movement toward precision medicine in cardiovascular disease. (16)

The present study was therefore designed to evaluate the association between the CHA_2DS_2-VASc score and prosthetic valve thrombosis in patients with mechanical aortic valve replacement within a real-world clinical cohort. By examining clinical characteristics alongside anticoagulation parameters, this investigation aims to determine whether CHA_2DS_2-VASc provides independent prognostic information beyond INR control. We hypothesize that the score does not independently predict aortic mechanical valve thrombosis, reinforcing the need for valve-specific predictive frameworks. Ultimately, improving risk prediction for prosthetic valve thrombosis has the potential to reduce morbidity, optimize anticoagulation strategies, and guide more individualized patient management. As mechanical valve implantation continues to play a central role in the treatment of valvular heart disease worldwide, refining our understanding of thrombosis risk and the tools used to assess it remains a clinical and scientific priority.

Material and methods

Study Design and Setting: The present study was designed as a case–control investigation conducted at Shahid Madani Heart Center, a tertiary referral hospital affiliated with Tabriz University of Medical Sciences, Tabriz, Iran. Patient recruitment and data collection were performed over a five-year period, from the beginning of 2017 to the end of 2021. The study population consisted of patients who had previously undergone mechanical mitral valve replacement and were followed regularly at the study center during the specified time frame.

Sampling

A census sampling strategy was employed, whereby all eligible patients meeting the predefined inclusion criteria during the study period were consecutively enrolled. Based on this approach, a total of 100 patients were included in the final analysis. Patients were categorized into two groups according to the presence or absence of confirmed prosthetic valve thrombosis, forming the case and control groups, respectively.

Inclusion and Exclusion Criteria: Eligible participants were adult patients aged 18 years or older who had undergone mechanical mitral valve replacement and case–control investigation conducted at Shahid Madani Heart Center, a tertiary referral hospital affiliated with Tabriz University of Medical Sciences, Tabriz, Iran. Patient recruitment and data collection were performed over a five-year period, from the beginning of 2017 to the end of 2021. The study population consisted of patients who had previously undergone mechanical mitral valve replacement and were followed regularly at the study center during the specified time frame.

Study Procedures: Baseline demographic characteristics, including age and sex, were extracted from medical records. Clinical variables such as hypertension, diabetes mellitus, heart failure, vascular disease, history of stroke or transient ischemic attack, and atrial fibrillation were systematically recorded. These variables were used to calculate the CHA_2DS_2-VASc score for each participant according to standard definitions. Echocardiographic parameters, including left ventricular ejection fraction and prosthetic valve function, were obtained from the most recent examinations prior to the diagnosis of thrombosis or the corresponding follow-up date in controls.

Anticoagulation-related data were carefully reviewed, including prescribed warfarin dose, recorded INR values, and INR status at the time of thrombosis diagnosis or last follow-up. For patients in the case group, INR values closest to the time of confirmed prosthetic valve thrombosis were analyzed. In the control group, INR measurements obtained during routine follow-up visits were used for comparison. All data were collected using a standardized data extraction form to minimize information bias.

The primary objective of the study was to evaluate the association between the CHA_2DS_2-, heart failure, vascular disease, history of stroke or transient ischemic attack, and atrial fibrillation were systematically recorded. These variables were used

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Statistical Analysis: Statistical analyses were performed using standard statistical software. Continuous variables were expressed as mean ± standard deviation or median with interquartile range, as appropriate, and were compared using the independent-samples t-test or Mann–Whitney U test. Categorical variables were presented as frequencies and percentages and were compared using the chi-square test or Fisher's exact test. Logistic regression analysis was used to identify independent predictors of prosthetic valve thrombosis, with results reported as odds ratios and 95% confidence intervals. A two-sided p-value of less than 0.05 was considered statistically significant.

Ethical Considerations: The study protocol was reviewed and approved by the Ethics Committee of Tabriz University of Medical Sciences (Ethics code: IR. TBZMED.1400.1256). This research was conducted in accordance with the principles of the Declaration of Helsinki. Patient confidentiality was strictly maintained, and all data were anonymized prior to analysis. The present study represents the results derived from Specific Objective No. 2 of the medical thesis, registered under Thesis Number: 67370.

Results

During a four-year observational period, a total of 104 patients were diagnosed with prosthetic valve thrombosis. Detailed review of anticoagulation status revealed that 82 of these patients (78%) had international normalized ratio (INR) values below or outside the therapeutic range, reflecting inadequate adherence to regular warfarin therapy. Because sub therapeutic anticoagulation represents a well-established confounding During a four-year observational period, a total of 104 patients were diagnosed with prosthetic valve thrombosis. Detailed review of anticoagulation status revealed that 82 of these patients (78%) had international normalized ratio (INR) values below or outside the therapeutic range, reflecting inadequate adherence to regular warfarin therapy. Because sub therapeutic anticoagulation represents a well-established confounding factor for prosthetic valve thrombosis, these patients were excluded from further analysis. Consequently, the study population consisted of 22 patients with confirmed prosthetic valve thrombosis who maintained INR values within the therapeutic range, along with 78 patients with mechanical prosthetic valves who had no clinical or imaging evidence of thrombosis and served as the control group.

The mean age of the overall study cohort was 54.93 ± 11.52 years. Patients in the thrombosis group had a mean age of 51.5 ± 14.68 years, while those without thrombosis had a mean age of 56 ± 10.31 years; this difference was not statistically significant (p=0.148) (Table 1-4). Regarding sex distribution, 62 patients (62%) were female and 38 patients (38%) were male. Comparison between the thrombosis and non-thrombosis groups demonstrated no significant difference in sex composition, indicating that gender was not associated with the occurrence of prosthetic valve thrombosis in this cohort (p=0.944).

Among the patients with mechanical prosthetic valves, 94% had a mechanical leaflet valve, and 6% had a mechanical monoleaflet valve. All patients experiencing thrombotic events had leaflet valves, but this difference was not statistically significant (p = 0.405). The left ventricular ejection fraction (EF) was similar between the two groups, with a mean EF of 44.5% in the thrombosis group and 45.18% in the non-thrombosis group, showing no significant difference (p=0.723) (table 1).

Regarding the time elapsed since valve surgery, patients with thrombosis had a longer mean postoperative duration (127 months) compared to those without thrombosis (100 months), but this was not statistically significant (p=0.149). The average warfarin dose was slightly higher in the thrombotic group (4.47 mg) versus the control group (4.33 mg), yet this difference was not statistically significant (p=0.447). Similarly, the mean INR values over the last three measurements were comparable between groups, with no significant variation (p = 0.620), indicating consistent anticoagulation management across the study population (table 1).

Table 1. Clinical Characteristics of Patients with Prosthetic Valves

Characteristic	Total Patients	No Thrombosis	With Thrombosis	P value
Valve Type				
Mechanical bileaflet	94 (94%)	72 (92.31%)	22 (100%)	0.405
Mechanical monoleaflet	6 (6%)	6 (7.69%)	NA	
Ejection Fraction (EF)*	44.94 (±10.39)	45.18 (±10.11)	44.5 (±11.58)	0.723
Time Since Surgery (months)*	105.51 (±87.5)	100 (±87.64)	127 (±83.38)	0.149
Warfarin Dose (mg)*	4.36 (±2.5)	4.33 (±2.12)	4.47 (±1.86)	0.447
Mean of Last 3 INR Measurements*	4.11 (±0.96)	4.6 (±0.84)	4.28 (±1.32)	0.620

Analysis of thrombosis location demonstrated that the mitral valve was the most frequently affected site, accounting for half of all thrombotic events. Isolated tricuspid valve thrombosis represented more than one-quarter of cases, while aortic valve involvement was less common. Concomitant thrombosis involving both the mitral and tricuspid valves was rare, observed in only a small minority of patients. When comparing left-sided and right-sided valve involvement, left-sided prosthetic valve thrombosis (mitral with or without aortic involvement) was more prevalent overall than isolated right-sided events. However, the relatively high proportion of tricuspid valve thrombosis highlights that right-sided mechanical valves are also susceptible to thrombotic complications, emphasizing the need for vigilant anticoagulation and follow-up regardless of valve position (figure 1).

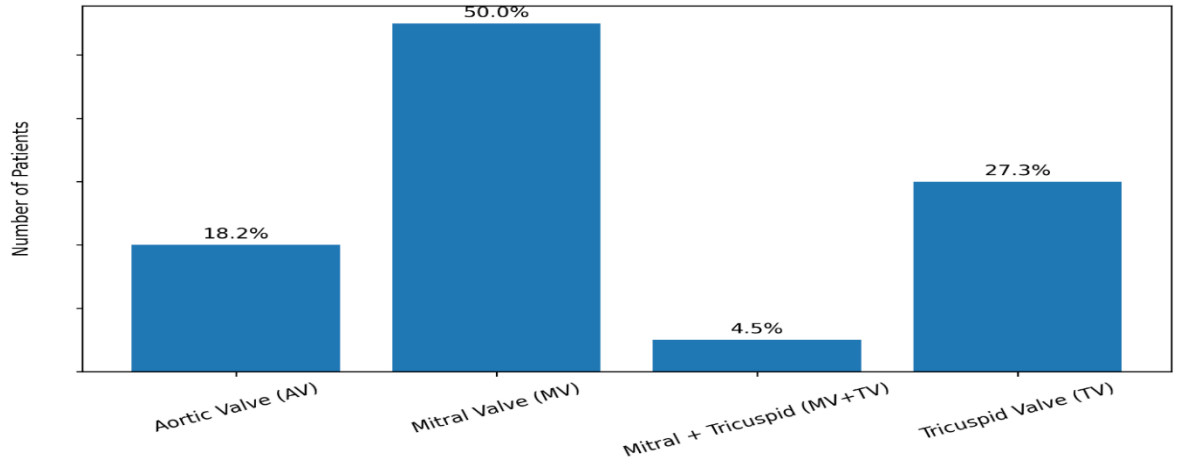

Figure 1. Location of Thrombosis in Prosthetic Valves

The overall mean CHA_2DS_2-VASc score in the study population was 2.58 ± 1.65. Patients with prosthetic valve thrombosis had a higher mean score (2.68 ± 1.63) compared with those without thrombosis (2.23 ± 1.72); however, this difference did not reach statistical significance ($p = 0.23$) (Figure 2). These findings indicate that, despite a numerically higher CHA_2DS_2-VASc score among patients who developed thrombosis, the score did not meaningfully discriminate between patients with and without thrombotic events in this cohort (figure 2).

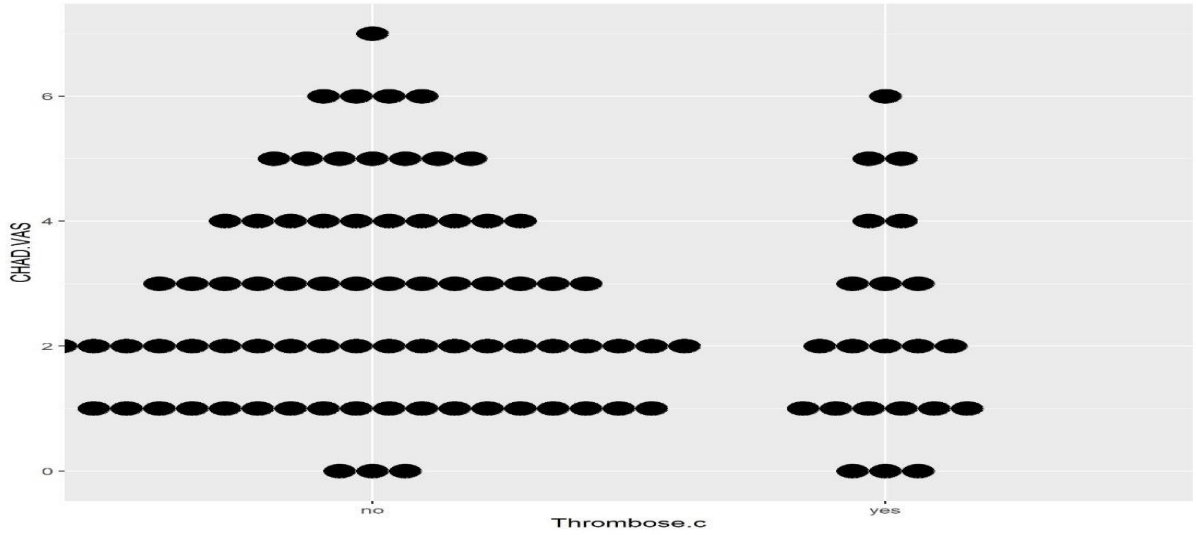

Figure 2. Comparison of CHA_2DS_2-VASc Scores Between Patients with and Without Prosthetic Valve Thrombosis

The mean CHA_2DS_2-VASc scores, analyzed according to prosthetic valve type, showed no significant differences between thrombotic and non-thrombotic groups. Among patients with aortic mechanical valves, the mean score was 3 ± 2 in the non-thrombosis group and 2 ± 2 in those with thrombosis ($p=0.841$). For mitral mechanical valves, both groups demonstrated similar mean scores of 3 ± 2 in non-thrombotic patients and 3 ± 2 in thrombotic patients ($p=0.204$) (figure 3).

When the CHA_2DS_2-VASc score was examined separately for aortic and mitral prostheses, no

meaningful difference emerged between patients with and without thrombosis. In the aortic valve subgroup, the thrombotic cohort actually had a slightly lower mean score than those without thrombosis, but the difference was statistically no significant. This indicates that the score did not distinguish patients at higher thrombotic risk among those carrying an aortic mechanical valve. Similarly, in the mitral valve subgroup, mean CHA_2DS_2-VASc scores were almost identical between individuals with thrombotic events and those without, again with no statistically significant separation. Collectively, these findings reinforce that the CHA_2DS_2-VASc score traditionally validated for predicting embolic risk in atrial fibrillation—offers limited discriminatory value for identifying prosthetic valve thrombosis risk, regardless of whether the prosthesis is located in the aortic or mitral position.

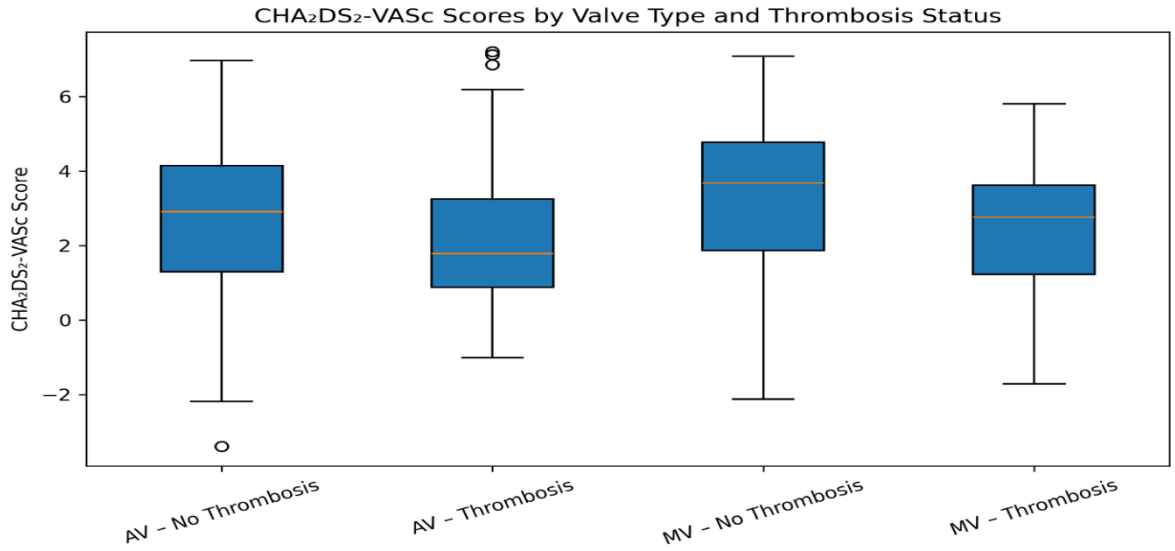

Figure 3. CHA_2DS_2-VASc Scores by Prosthetic Valve Type and Thrombosis Status

Discussion

The present study sought to evaluate the usefulness of the CHA_2DS_2-VASc score in predicting prosthetic valve thrombosis within a cohort of patients with mechanical valves who maintained therapeutic anticoagulation. Overall, the findings demonstrated that commonly used clinical risk stratification tools, particularly the CHA_2DS_2-VASc score, were unable to effectively discriminate between patients who developed thrombosis and those who did not, despite careful control for anticoagulation quality. This highlights the complexity of thrombotic mechanisms in patients with mechanical prosthetic valves and suggests that factors beyond traditional cardiovascular risk profiles play a dominant role in thrombosis development in this population (17,18).

A key methodological strength of this study was the deliberate exclusion of patients with inadequate anticoagulation control. Poor adherence to warfarin therapy and sub therapeutic anticoagulation are well-established contributors to prosthetic valve thrombosis and can obscure the assessment of other potential risk factors. By restricting the analysis to patients with stable and therapeutic anticoagulation, the study minimized this major confounding influence, allowing for a more focused evaluation of clinical and demographic predictors. The persistence of thrombosis despite appropriate anticoagulation underscores the multifactorial nature of this complication and suggests that current clinical tools may be insufficient to capture its true risk profile (19,20).

Demographic characteristics such as age and sex did not differ meaningfully between patients with and without thrombosis, indicating that baseline population characteristics were unlikely to account for thrombotic risk in this cohort. Although age and sex are central components of many cardiovascular risk models, their limited relevance in this setting likely reflects the dominant influence of prosthesis-related and hemodynamic factors. Mechanical valves introduce non-physiological flow patterns and shear stress that may override the effects of demographic variables traditionally associated with thromboembolic disease (21,22).

Valve-related characteristics were also explored to determine whether prosthesis design influenced thrombotic outcomes. Although leaflet mechanical valves were the predominant valve type in the cohort, no meaningful association was observed between valve design and thrombosis occurrence. This finding aligns with previous evidence suggesting that modern leaflet valves, while generally associated with improved hemodynamics, still carry an inherent chromogenic risk due to altered flow dynamics and surface interactions. The absence of a detectable difference may reflect the

uniformly high chromogenic potential of mechanical prostheses rather than true equivalence between valve types (23,24).

Cardiac functional parameters, including left ventricular systolic performance, were similar between groups and did not appear to influence thrombosis risk. Ventricular dysfunction has historically been associated with blood stasis and thrombus formation; however, in the setting of mechanical valves, the localized hemodynamic disturbances introduced by the prosthesis itself may be more critical than global ventricular performance. This observation suggests that systemic cardiac function alone may not adequately reflect the localized prothrombotic environment surrounding mechanical valves (25,26).

The duration since valve implantation was longer among patients who developed thrombosis, although this difference did not translate into a meaningful predictor. This finding raises the possibility that chronic prosthesis-related changes, such as pannus formation, endothelial dysfunction, or gradual alterations in flow patterns, may contribute to thrombosis risk over time. However, the lack of a clear association suggests that time since surgery alone is insufficient as a predictive marker and that thrombosis may arise from episodic or cumulative factors rather than linear temporal progression (27,28).

Anticoagulation parameters, including warfarin dosage and INR stability, were comparable between groups, reinforcing the notion that thrombosis can occur even under apparently optimal anticoagulation management. This challenges the assumption that therapeutic INR levels uniformly protect against thrombotic complications and highlights the limitations of INR as a surrogate marker for true antith without thrombosis, indicating that baseline population characteristics were unlikely to account for thrombotic risk in this cohort. Although age and sex are central components of many cardiovascular risk models, their limited relevance in this setting likely reflects the dominant influence of prosthesis-related and hemodynamic factors. Mechanical valves introduce non-physiological flow patterns and shear stress that may override the effects of demographic variables traditionally associated with thromboembolic disease (29,30).

Analysis of thrombosis distribution revealed a predominance of left-sided valve involvement, particularly affecting the mitral position, although right-sided thrombosis was also observed with notable frequency. The higher susceptibility of left-sided valves is consistent with greater pressure gradients and more complex flow patterns, which may promote platelet activation and thrombus formation. Nonetheless, the substantial occurrence of right-sided valve thrombosis challenges the perception that these valves are relatively protected and underscores the need for vigilance across all prosthetic valve positions (31,32).

The CHA_2DS_2-VASc score, when applied to the overall cohort, showed a tendency toward higher values among patients with thrombosis but failed to achieve meaningful discriminatory performance. This finding reflects a fundamental limitation of the score, which was originally developed to estimate embolic risk in atrial fibrillation rather than thrombosis on prosthetic material. The score emphasizes systemic vascular risk factors but does not incorporate valve-specific or anticoagulation the localized hemodynamic disturbances introduced by the prosthesis itself may be more critical than global ventricular performance. This observation suggests that systemic cardiac function alone may not adequately reflect the localized prothrombotic environment surrounding mechanical valves (33,34).

When stratified by valve position, the CHA_2DS_2-VASc score remained unable to differentiate thrombotic from non-thrombotic patients in both aortic and mitral subgroups. This consistency across valve types strengthens the conclusion that the score lacks valve-specific predictive value. Aortic mechanical valves, despite distinct hemodynamic profiles compared with mitral valves, did not exhibit differential associations with CHA_2DS_2-VASc components, and transient prothrombotic states may all contribute to residual risk despite guideline-directed therapy (35,36).

The failure of the CHA_2DS_2-VASc score to predict thrombosis in this setting likely reflects its omission of critical mechanistic factors such as prosthesis geometry, leaflet motion abnormalities, endothelial response to foreign material, and inflammatory activation. Prosthetic valve thrombosis is a localized process influenced by device-tissue interaction, which is poorly captured by systemic risk scores. This disconnect highlights the need for valve-specific risk assessment tools that integrate mechanical, biological, and patient-related variables (37,38).

From a clinical perspective, reliance on CHA_2DS_2-VASc scoring to estimate thrombosis risk in patients with mechanical valves may provide false reassurance or misclassification. While the score remains valuable in atrial fibrillation management, its extrapolation to prosthetic valve populations should be approached with caution. Clinicians should prioritize individualized assessment, incorporating imaging findings, valve function surveillance, and anticoagulation consistency rather than depending solely on generalized cardiovascular risk scores (39,40).

The findings of this study align with emerging evidence questioning the applicability of traditional thromboembolic risk models in specialized populations. Mechanical valve recipients represent a distinct group in whom thrombosis is driven by

unique mechanisms that differ fundamentally from native-valve or atrial fibrillation–related embolism. Future research should focus on developing and validating predictive models tailored specifically to prosthetic valve thrombosis, potentially incorporating biomarkers, advanced imaging parameters, and prosthesis-specific characteristics (41,42).

In summary, this study demonstrates that even under therapeutic anticoagulation conditions, prosthetic valve thrombosis remains an unpredictable and multifactorial complication. The CHA_2DS_2-VASc score did not provide meaningful prognostic information for thrombosis risk, either overall or when stratified by valve type. These findings underscore the challenges inherent in predicting aortic mechanical valve thrombosis and emphasize the need for novel, valve-specific risk stratification approaches to improve prevention and clinical outcomes in this high-risk population.

Conclusion

In this cohort of patients with mechanical prosthetic valves who maintained therapeutic anticoagulation, traditional clinical and demographic factors were not associated with the development of prosthetic valve thrombosis. Despite its established role in estimating thromboembolic risk in atrial fibrillation, the CHA_2DS_2-VASc score demonstrated limited utility in identifying patients at increased risk of thrombosis, either overall or when stratified by valve position. These findings underscore the complex and multifactorial nature of prosthetic valve thrombosis and suggest that risk prediction in this population cannot rely solely on conventional cardiovascular risk scores. Future studies should focus on developing valve-specific risk stratification models that integrate prosthesis-related characteristics, advanced imaging findings, and biological markers to improve prediction and prevention of thrombotic complications in patients with mechanical valves.

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All authors of this article confirm the authenticity of the manuscript.

Conflicts of interest

The authors declare that they have no competing interests.

Disclosure Statement

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Authors' Contributions

All authors contributed to data analysis, drafting, and revising of the paper and agreed to be responsible for all the aspects of this work.

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