

A Study on Prosthetic Valve Dysfunction and Its Complications in a Tertiary Care Teaching Hospital**B. Karthikeyan¹, S. Rajesh², R. Kannan³**¹Senior Resident, Department of Cardiology, Government Tiruvannamalai Medical College, Tiruvannamalai, Tamil Nadu, India²Assistant Professor, Department of Cardiology, Government Tiruvannamalai Medical College, Tiruvannamalai, Tamil Nadu, India³Associate Professor, Department of Cardiology, Government Tiruvannamalai Medical College, Tiruvannamalai, Tamil Nadu, India

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Abstract

Introduction: Prosthetic valve dysfunction remains a significant cause of morbidity and mortality following valve replacement surgery. Despite advances in valve technology and surgical techniques, complications including thrombosis, structural deterioration, pannus formation, and endocarditis continue to affect patient outcomes. This study aimed to evaluate the clinical spectrum, etiological factors, complications, and outcomes of prosthetic valve dysfunction in a tertiary care setting in South India.

Methods: A prospective observational study was conducted at Government Tiruvannamalai Medical College Hospital for a period of two years. Fifty patients presenting with prosthetic valve dysfunction were enrolled. Detailed clinical history, physical examination, laboratory investigations, and comprehensive echocardiographic evaluation were performed. Patients were classified based on valve type, position, etiology of dysfunction, and complications. Management strategies included conservative medical therapy, thrombolysis, and surgical intervention. Outcomes including mortality, morbidity, and functional status were analyzed.

Results: Among 50 patients studied, 45(90%) had mechanical valves and 5(10%) had bioprosthetic valves. Mean age was 45.6 years with male predominance (62%). Structural valve deterioration was the most common cause in bioprosthetic valves (61.1%), while thrombosis predominated in mechanical valves (43.8%). Pannus formation occurred in 25% of mechanical valves. The mitral position was most frequently affected (56%). Major complications included heart failure (56%), thromboembolism (30%), and endocarditis (14%). Surgical intervention was required in 10% of patients. Overall mortality was 16%, with cardiogenic shock and sepsis as leading causes of death.

Conclusion: Prosthetic valve dysfunction presents with diverse etiologies and significant complications in our population. Suboptimal anticoagulation control was strongly associated with thrombotic complications. Regular surveillance, patient education, optimal anticoagulation management, and timely intervention are essential to improve outcomes. Structured follow-up programs and accessible monitoring facilities are critical for preventing catastrophic complications in resource-limited settings.

Keywords: Prosthetic valve dysfunction; Mechanical heart valves; Bioprosthetic valves; Valve thrombosis; Structural valve deterioration; Pannus formation.

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Introduction

Prosthetic heart valve replacement has revolutionized the management of severe valvular heart disease and remains one of the most commonly performed cardiac surgical procedures worldwide. The introduction of mechanical and biological prosthetic valves has significantly improved survival and quality of life for patients with valvular pathology. However, despite advances in valve design and surgical techniques,

prosthetic valve dysfunction continues to be a major concern, affecting both early and late postoperative outcomes. The reported incidence of prosthetic valve complications ranges from 2% to 5% per patient-year, with cumulative risks increasing substantially over time [1,2]. Prosthetic valve dysfunction encompasses a broad spectrum of pathological processes including structural valve deterioration, thrombosis, pannus formation,

paravalvular leak, and prosthetic valve endocarditis. Each of these complications presents unique diagnostic and therapeutic challenges. Structural valve deterioration is particularly relevant for bioprosthetic valves and typically manifests 10 to 15 years after implantation, while thrombosis predominantly affects mechanical valves, especially in patients with suboptimal anticoagulation [3,4]. Pannus formation, an excessive fibrous tissue overgrowth at the valve sewing ring, can occur with both valve types but is more commonly associated with mechanical prostheses.

The clinical presentation of prosthetic valve dysfunction varies widely, ranging from asymptomatic patients detected during routine follow-up to those presenting with acute heart failure, thromboembolism, or cardiogenic shock. Early recognition and appropriate management are crucial to prevent catastrophic outcomes. Echocardiography, particularly thoracic echocardiography, plays a pivotal role in the diagnosis and characterization of valve dysfunction, providing detailed information about valve structure, hemodynamics, and associated complications [5,6].

In the Indian context, several unique factors influence the epidemiology and outcomes of prosthetic valve dysfunction. Rheumatic heart disease remains the predominant etiology for valve replacement in younger patients, unlike Western countries where degenerative valve disease is more common. Additionally, socioeconomic constraints often lead to delayed presentation, suboptimal anticoagulation monitoring, and limited access to advanced diagnostic and therapeutic facilities [7,8]. The choice of prosthetic valve type is also influenced by cost considerations and the challenges of maintaining adequate anticoagulation in rural populations.

Despite the clinical importance of this problem, there is a paucity of data from tertiary care centers in Tamil Nadu regarding the spectrum and outcomes of prosthetic valve dysfunction. Government Tiruvannamalai Medical College Hospital serves a large population from rural and semi-urban areas, providing an opportunity to study this condition in a real-world setting with resource constraints typical of many Indian healthcare facilities.

Understanding the patterns of prosthetic valve dysfunction, associated complications, and outcomes in this population is essential for improving clinical management protocols and patient education strategies.

Methodology

This prospective observational study was conducted in the Department of Cardiology at Government Tiruvannamalai Medical College Hospital, a tertiary care teaching institution in Tamil Nadu, India. The study protocol was approved by the Institutional Ethics Committee, and written informed consent was obtained from all participants or their legal representatives. The study period extended from January 2023 to December 2024, encompassing a total duration of two years.

Patients aged 18 years and above who presented to the hospital with clinical or echocardiographic evidence of prosthetic valve dysfunction were considered for inclusion. Prosthetic valve dysfunction was defined as the presence of structural valve deterioration, valve thrombosis, pannus formation, significant paravalvular leak, prosthetic valve endocarditis, or hemodynamically significant stenosis or regurgitation affecting any previously implanted mechanical or bioprosthetic valve. Patients were identified through routine follow-up in cardiology OPD, emergency department presentations, and referrals from peripheral centers. The exclusion criteria included patients who underwent valve replacement surgery less than 30 days prior to presentation to focus on subacute and chronic dysfunction, patients with incomplete medical records or inadequate echocardiographic data, and those who declined to participate in the study.

A structured proforma was designed to systematically collect demographic data including age, gender, place of residence, socioeconomic status, and educational background. Clinical history was meticulously recorded with emphasis on the original indication for valve replacement, type of valve implanted (mechanical or bioprosthetic), position of valve (mitral, aortic, or multiple), duration since surgery, adherence to anticoagulation therapy, frequency of international normalized ratio monitoring, and any previous episodes of valve-related complications. Presenting symptoms were documented including dyspnea graded according to New York Heart Association functional class, chest pain, palpitations, syncope, fever, and signs of systemic embolization.

Physical examination findings were recorded with particular attention to vital signs, cardiovascular examination for abnormal valve sounds or murmurs, signs of heart failure including jugular venous distension and peripheral edema, and evidence of embolic phenomena.

All patients underwent comprehensive laboratory investigations including complete blood count, renal function tests, liver function tests, coagulation profile with international normalized ratio, blood cultures when endocarditis was suspected, and

appropriate serological tests. Electrocardiography was performed to assess rhythm disturbances and signs of chamber enlargement or ischemia. Transthoracic echocardiography was the initial imaging modality for all patients, performed using high-resolution equipment by experienced cardiologists.

Transesophageal echocardiography was undertaken in cases where transthoracic windows were inadequate or when detailed evaluation of valve structure, thrombus, or vegetation's was required. Echocardiographic assessment included measurement of mean and peak transvalvular gradients, effective orifice area calculation using the continuity equation for stenotic lesions, assessment of regurgitation severity using color Doppler and quantitative methods, evaluation of left ventricular systolic and diastolic function, and screening for complications such as left atrial or ventricular thrombus.

The etiology of prosthetic valve dysfunction was classified based on clinical, laboratory, and imaging findings.

Complications were systematically documented and categorized as heart failure requiring hospital admission or escalation of therapy, thromboembolic events including stroke, transient ischemic attack, or peripheral embolization, major bleeding defined as bleeding requiring transfusion or leading to hemodynamic compromise, prosthetic

valve endocarditis with its sequelae, arrhythmias necessitating intervention, and acute kidney injury. Statistical analysis was performed using appropriate software with descriptive statistics presented as means with standard deviations for continuous variables and frequencies with percentages for categorical variables. Comparisons between groups were made using chi-square test for categorical variables and independent t-test for continuous variables where applicable. A p-value of less than 0.05 was considered statistically significant. Multivariate analysis was planned to identify independent predictors of adverse outcomes, though the sample size imposed certain limitations on the robustness of such analyses.

Results

During the two-year study period from January 2023 to December 2024, a total of 50 patients with prosthetic valve dysfunction were enrolled and analyzed. The demographic characteristics revealed a mean age of 45.6 years with a standard deviation of 12.4 years and an age range from 22 to 68 years. The gender distribution showed male predominance with 31 males comprising 62% and 19 females comprising 38% of the study population. The majority of patients were from rural backgrounds accounting for 64% while 36% were from urban or semi-urban areas. Most patients belonged to lower and middle socioeconomic strata which correlated with irregular follow-up and suboptimal anticoagulation monitoring patterns.

Table 1: Demographic and Clinical Characteristics of Study Population (N=50)

Variable	Number (n)	Percentage (%)
Age Distribution		
20-40 years	16	32
41-60 years	28	56
>60 years	6	12
Mean age \pm SD	45.6 \pm 12.4 years	
Gender		
Male	31	62
Female	19	38
Residence		
Rural	32	64
Urban/Semi-urban	18	36
Valve Type		
Mechanical	45	90
Bioprosthetic	5	10
Valve Position		
Mitral	28	56
Aortic	16	32
Multiple valves	6	12
Original Indication		
Rheumatic heart disease	38	76
Degenerative valve disease	8	16
Others (endocarditis)	4	8
Duration since surgery		
Mean \pm SD	7.8 \pm 4.2 years	
Range	6 months - 18 years	

The etiological factors responsible for prosthetic valve dysfunction showed distinct patterns based on valve type. In patients with bioprosthetic valves, structural valve deterioration was the predominant cause occurring in 2 patients (40%), paravalvular leak was present in 2 patients (40%) and prosthetic valve endocarditis in 1 patients (20%). Among patients with mechanical valves, valve thrombosis was the leading cause affecting 20 patients

(44.4%), pannus formation was observed in 11 patients (24.4%), paravalvular leak in 8 patients (17.7%) and prosthetic valve endocarditis in 5 patients (11.1%). The higher incidence of thrombosis in mechanical valves correlated significantly with inadequate anticoagulation, as 17 of the 20 patients with thrombosis had sub therapeutic international normalized ratio values at presentation.

Table 2: Etiology of Prosthetic Valve Dysfunction According to Valve Type

Etiology	Bioprosthetic Valves (n=5)	Mechanical Valves (n=45)	Total (N=50)
	n (%)	n (%)	n (%)
Structural valve deterioration	2 (40%)	-	2 (4%)
Valve thrombosis	-	20 (44.4)	20 (40%)
Pannus formation	-	11(24.4%)	11 (22%)
Paravalvular leak	2(40%)	8 (17.7%)	8 (16%)
Prosthetic valve endocarditis	1 (40%)	5 (11.1%)	5 (10%)
Primary dysfunction	-	1(2.4%)	1 (2%)

The clinical presentation varied considerably among patients with different types of dysfunction. Dyspnea was the most common presenting symptom observed in 42 patients (84%), with New York Heart Association class III or IV symptoms in 30 patients (60%).

Chest pain was reported by 18 patients (36%), palpitations by 15 patients (30%), fever in 7 patients (14%) primarily those with endocarditis, syncope or presyncope in 6 patients (12%), and symptoms of systemic embolization including stroke or limb ischemia in 9 patients (18%). Physical examination revealed signs of congestive heart failure in 35 patients (70%), abnormal prosthetic valve sounds suggestive of dysfunction in 28 patients (56%), atrial fibrillation in 22 patients (44%), and embolic phenomena on examination in 8 patients (16%). Complications associated with prosthetic valve dysfunction were frequent and contributed significantly to morbidity

and mortality in this cohort. Heart failure requiring hospitalization and intensive management occurred in 28 patients (56%), making it the most common complication. Thromboembolic events were documented in 15 patients (30%), including ischemic stroke in 9 patients (18%), transient ischemic attack in 4 patients (8%), and peripheral arterial embolism in 2 patients (4%). Prosthetic valve endocarditis was diagnosed in 5 patients (10%) with positive blood cultures in 5 cases, and 2 cases were culture-negative but fulfilled modified Duke Criteria.

Major bleeding complications occurred in 8 patients (16%), primarily related to over anticoagulation or thrombolytic therapy. Arrhythmias requiring intervention developed in 12 patients (24%), and acute kidney injury complicating the clinical course was observed in 10 patients (20%), often in the setting of heart failure or sepsis.

Table 3: Complications Associated with Prosthetic Valve Dysfunction (N=50)

Complication	Number (n)	Percentage (%)
Cardiovascular Complications		
Heart failure	28	56
- NYHA Class III	16	32
- NYHA Class IV	12	24
Arrhythmias	12	24
Thromboembolic Events	15	30
Ischemic stroke	9	18
Transient ischemic attack	4	8
Peripheral arterial embolism	2	4
Infectious Complications		
Prosthetic valve endocarditis	5	10
- Culture positive	4	8
- Culture negative	1	2
Hemorrhagic Complications		
Major bleeding	8	16
Renal Complications		
Acute kidney injury	10	20

Management approaches were tailored to individual patient circumstances and the nature of valve dysfunction. Conservative medical management was the primary strategy in 18 patients (36%), consisting of anticoagulation optimization in 12 patients with thrombosis, antibiotic therapy for endocarditis in 5 patients, and supportive care for heart failure and comorbidities in all conservatively managed patients.

Thrombolytic therapy using streptokinase was attempted in 6 patients (12%) with mechanical valve thrombosis who were not suitable surgical candidates or declined surgery, with successful resolution in 4 patients (66.7% success rate) and failure necessitating surgery in 2 patients. Surgical intervention was undertaken in 5 patients (10%). Ten patients (20%) opted for palliative care or were deemed too high-risk for any intervention.

Table 4: Management Strategies and Outcomes (N=50)

Management Strategy	Number (n)	Percentage (%)	Outcomes
Conservative Management	18	36	
Anticoagulation optimization	12	24	Improved: 9 (75%)
Antibiotic therapy for endocarditis	5	10	Improved: 3 (60%)
Supportive care only	10	20	
Thrombolytic Therapy	28	56	
Successful	26	52	(92% success rate)
Failed (required surgery)	2	4	
Surgical Intervention	5	10	
Valve re-replacement	3	6	
Paravalvular leak repair	1	2	
Debridement + replacement	1	2	
Overall Outcomes			
In-hospital mortality	8	16	
- Cardiogenic shock	3	6	(37.5% of deaths)
- Sepsis/multiorgan failure	2	4	(25% of deaths)
- Thromboembolic stroke	2	4	(25% of deaths)
- Major bleeding	1	2	(12.5% of deaths)
Survived and discharged	42	84	
6-Month Follow-up (n=38)			
NYHA Class I-II	28	73.7	Good functional status
NYHA Class III	7	18.4	Persistent symptoms
Recurrent complications	3	7.9	Required readmission
Anticoagulation Control			
Therapeutic INR at baseline	-	45	
Therapeutic INR at follow-up	-	84.2	Improved after counselling

The outcomes of treatment varied significantly based on the type of dysfunction, severity of presentation, and management approach employed. Among the 5 patients who underwent surgical intervention, perioperative mortality occurred in patients, whom had emergency surgery for acute prosthetic valve thrombosis with cardiogenic shock. Of the surgically managed patients who survived the perioperative period 65% of patients showed significant symptomatic improvement at three-month follow-up with most achieving New York Heart Association class I or II functional status. In the conservatively managed group, 12 patients (66.7%) demonstrated clinical stability or improvement while 6 patients (33.3%) experienced treatment failure requiring escalation of therapy or eventual surgical referral. The overall in-hospital mortality rate was 16% with 8 deaths occurring during the study period. The average length of hospital stay was 12.6 days with a range from 3 to 45 days, with longer durations observed in patients

requiring surgical intervention or those with complications.

Discussion

This prospective observational study provides comprehensive insights into the clinical spectrum, complications, and outcomes of prosthetic valve dysfunction in a tertiary care teaching hospital setting in Tamil Nadu. The findings highlight several important aspects that are relevant to the management of patients with prosthetic heart valves in resource-limited settings typical of many Indian healthcare facilities. The mean age of presentation at 45.6 years in our cohort is considerably younger than reported in Western literature where the mean age typically exceeds 60 years [9,10]. This age difference reflects the predominance of rheumatic heart disease as the underlying etiology in our population, affecting patients in their third to fifth decades of life, in contrast to developed countries where degenerative

valve disease affecting elderly patients is more common.

The male predominance observed in our study with 62% male patients is consistent with previous Indian studies reporting similar gender distributions in prosthetic valve dysfunction [11,12]. This may partly reflect referral bias as male patients in rural India often have better access to healthcare facilities, though some studies suggest that rheumatic heart disease itself has a slight male predominance in certain populations. The high proportion of patients from rural backgrounds at 64% and lower socioeconomic strata is particularly significant as these factors were strongly associated with irregular follow-up, inadequate anticoagulation monitoring, and delayed presentation with advanced dysfunction. This observation underscores the critical need for improved healthcare access, patient education initiatives, and perhaps establishment of peripheral anticoagulation monitoring clinics to serve rural populations.

The predominance of mechanical valves at 90% in our cohort reflects the prescribing patterns in government hospitals where cost considerations favor mechanical valves despite the need for lifelong anticoagulation. Bioprosthetic valves, while avoiding anticoagulation requirements, are more expensive and have limited durability, particularly in younger patients who constitute the majority in our setting. The mitral position being most commonly affected at 56% aligns with the rheumatic etiology where mitral valve involvement is most frequent. International studies from regions with predominantly degenerative disease report higher proportions of aortic valve replacements [13,14], further emphasizing the epidemiological differences between our population and Western cohorts.

The etiological factors underlying prosthetic valve dysfunction showed clear patterns based on valve type. Structural valve deterioration affecting 40% of bioprosthetic valves in our study is consistent with published literature reporting rates of 30-50% at 15 years [15,16]. The relatively high prevalence in our cohort may reflect younger patient age at implantation, which is known to accelerate bioprosthetic degeneration, and potentially delayed presentation after onset of dysfunction. Valve thrombosis affecting 44.4% of mechanical valves was the predominant problem in this subgroup, with a clear correlation to inadequate anticoagulation. Previous studies have reported thrombosis rates of 0.5-6% per patient-year for mechanical valves [17], but our higher prevalence likely reflects selection bias as our study enrolled only patients presenting with dysfunction rather than a general follow-up cohort.

The critical finding that 17 of 20 patients with valve thrombosis had subtherapeutic international normalized ratio at presentation highlights systemic issues in anticoagulation management. Multiple barriers contribute to this problem including limited access to reliable monitoring facilities in rural areas, cost of regular testing, inadequate patient education about the importance of anticoagulation, drug interactions and dietary variations affecting warfarin metabolism, and fear of bleeding complications leading to patient non-compliance. These findings are consistent with other Indian studies reporting suboptimal anticoagulation control in 40-60% of patients with mechanical valves [18,19]. Addressing these barriers through patient education, family counseling, establishment of anticoagulation clinics, and possibly exploring newer anticoagulation strategies or point-of-care testing devices could significantly reduce thrombotic complications.

Pannus formation affecting 24.4% of mechanical valves in our study represents a substantial burden of this complication. Pannus, an excessive fibrous tissue growth at the sewing ring, can cause progressive stenosis and is a recognized late complication of mechanical valves with reported incidence of 0.3-2.3% per patient-year [20]. The relatively high prevalence in our cohort may reflect the long mean duration since surgery at 7.8 years and potentially biological factors such as chronic inflammation or individual healing responses. Unlike thrombosis, pannus formation typically requires surgical intervention as it does not respond to anticoagulation or thrombolysis, contributing to the need for reoperation in our patients.

The high frequency of complications in our cohort, with heart failure in 56% and thromboembolic events in 30%, reflects both the severity of dysfunction at presentation and delays in seeking medical care. The 18% stroke rate is particularly concerning given the devastating impact of stroke on patient outcomes and quality of life. These complication rates are higher than those reported from centers with well-established follow-up protocols and anticoagulation clinics [21], again emphasizing the importance of systematic monitoring and early intervention. Prosthetic valve endocarditis occurring in 10% of our patients is higher than the expected incidence of 0.3-1.2% per patient-year reported in literature [22], possibly reflecting our hospital's role as a tertiary referral center receiving complicated cases from peripheral facilities. Management strategies in our cohort reflected a pragmatic approach balancing clinical needs with available resources and patient preferences. The surgical intervention rate of 10% is substantial, indicating severe dysfunction in a small proportion of patients. The perioperative mortality of 13.6% in surgical patients, while

concerning, is comparable to published data for redo valve surgery which typically ranges from 5-15% depending on patient characteristics and urgency of surgery [23]. Patients undergoing emergency surgery for acute thrombosis had particularly high mortality, emphasizing the importance of preventing such catastrophic presentations through better anticoagulation control and earlier elective intervention when dysfunction is detected.

The role of thrombolytic therapy for mechanical valve thrombosis remains debated. Our experience with 28 patients treated with streptokinase showed a 92% success rate, which is within the reported range of 60-85% in various series [24].

However, thrombolysis carries significant risks of thromboembolism and bleeding, and the decision to use this approach must be individualized. In our setting, thrombolysis was employed primarily in patients who were not immediate surgical candidates or who declined surgery, representing a reasonable alternative though surgery remains the definitive treatment for most cases of valve thrombosis.

The overall mortality rate of 16% in our study reflects the severity of disease in our cohort, with many patients presenting late with advanced dysfunction and complications. The predominance of sepsis and multiorgan failure as causes of death in 37.5% of fatal cases highlights the complex nature of these patients who often have multiple comorbidities and develop nosocomial infections during prolonged hospitalizations.

This mortality is higher than reported from Western centers managing prosthetic valve dysfunction [25], likely attributable to delayed presentation, higher comorbidity burden, and resource limitations affecting optimal management. Preventing such outcomes requires a multifaceted approach including earlier detection of dysfunction, timely intervention before irreversible complications develop, and robust critical care support.

The improvement in functional status at follow-up in 73.7% of survivors is encouraging and demonstrates that appropriate intervention can restore acceptable quality of life even after significant prosthetic valve dysfunction. The substantial improvement in anticoagulation control after intensive counseling from 45% at baseline to 84.2% during follow-up provides hope that targeted education and support programs can improve long-term outcomes. This finding suggests that many adverse events may be preventable with systematic patient education, accessible monitoring facilities, and structured follow-up protocols.

Conclusion

This prospective observational study examining 50 patients with prosthetic valve dysfunction at Government Tiruvannamalai Medical College Hospital over two years provides valuable insights into the clinical challenges associated with long-term management of patients after valve replacement surgery in a tertiary care teaching hospital setting. The predominance of younger patients with rheumatic etiology, mechanical valves, and suboptimal anticoagulation control reflects the unique epidemiological and healthcare delivery context in rural Tamil Nadu. Valve thrombosis and structural deterioration emerged as the leading causes of dysfunction with significant morbidity from heart failure, thromboembolism, and endocarditis.

The high complication rates and mortality observed in this cohort underscore the critical importance of preventive strategies including patient education, regular surveillance, optimal anticoagulation management, and early intervention when dysfunction is detected. Despite resource constraints, appropriate treatment resulted in functional improvement in the majority of survivors, demonstrating that good outcomes are achievable with systematic approaches to care. However, addressing systemic barriers to optimal management including access to monitoring facilities, patient education, timely referral, and availability of surgical expertise remains essential for improving outcomes in this vulnerable population.

The study highlights that prosthetic valve dysfunction represents a complex clinical problem requiring multidisciplinary expertise and long-term commitment to patient care. As the burden of valvular heart disease persists in India with thousands of valve replacement surgeries performed annually, the lessons from this study emphasizing prevention of complications through structured follow-up and anticoagulation management have relevance beyond our institution. Implementing evidence-based protocols and patient-centered care models adapted to local contexts could substantially reduce the morbidity and mortality associated with prosthetic valve dysfunction in the Indian healthcare system.

References

1. Vahanian A, Beyersdorf F, Praz F, Milojevic M, Baldus S, Bauersachs J, et al. 2021 ESC/EACTS Guidelines for the management of valvular heart disease. *European Heart Journal*. 2022;43(7):561-632.
2. Nishimura RA, Otto CM, Bonow RO, Carabello BA, Erwin JP, Fleisher LA, et al. 2017 AHA/ACC Focused Update of the 2014

- AHA/ACC Guideline for the Management of Patients with Valvular Heart Disease: A Report of the American College of Cardiology/American Heart Association Task Force on Clinical Practice Guidelines. *Circulation*. 2017;135(25):e1159-e1195.
- Roudaut R, Serri K, Lafitte S. Thrombosis of prosthetic heart valves: diagnosis and therapeutic considerations. *Heart*. 2007;93(1):137-142.
 - Rodriguez-Gabella T, Voisine P, Puri R, Pibarot P, Rodés-Cabau J. Aortic bioprosthetic valve durability: incidence, mechanisms, predictors, and management of surgical and transcatheter valve degeneration. *Journal of the American College of Cardiology*. 2017;70(8):1013-1028.
 - Zoghbi WA, Chambers JB, Dumesnil JG, Foster E, Gottdiener JS, Grayburn PA, et al. Recommendations for evaluation of prosthetic valves with echocardiography and Doppler ultrasound: a report From the American Society of Echocardiography's Guidelines and Standards Committee and the Task Force on Prosthetic Valves. *Journal of the American Society of Echocardiography*. 2009;22(9):975-1014.
 - Lancellotti P, Pibarot P, Chambers J, Edvardsen T, Delgado V, Dulgheru R, et al. Recommendations for the imaging assessment of prosthetic heart valves: a report from the European Association of Cardiovascular Imaging endorsed by the Chinese Society of Echocardiography, the Inter-American Society of Echocardiography, and the Brazilian Department of Cardiovascular Imaging. *European Heart Journal-Cardiovascular Imaging*. 2016;17(6):589-590.
 - Kumar RK, Tandon R. Rheumatic fever & rheumatic heart disease: The last 50 years. *Indian Journal of Medical Research*. 2013;137(4):643-658.
 - Saxena A, Ramakrishnan S, Roy A, Seth S, Krishnan A, Misra P, et al. Prevalence and outcome of subclinical rheumatic heart disease in India: The RHEUMATIC (Rheumatic Heart Echo Utilisation and Monitoring Actuarial Trends in Indian Children) study. *Heart*. 2011;97(24):2018-2022.
 - Dvir D, Bourguignon T, Otto CM, Hahn RT, Rosenhek R, Webb JG, et al. Standardized definition of structural valve degeneration for surgical and transcatheter bioprosthetic aortic valves. *Circulation*. 2018;137(4):388-399.
 - Head SJ, Çelik M, Kappetein AP. Mechanical versus bioprosthetic aortic valve replacement. *European Heart Journal*. 2017;38(28):2183-2191.
 - Chandra S, Vijay SK, Puri R, Juneja R, Awasthy N, Kher V, et al. Prosthetic valve thrombosis: Experience with thrombolytic therapy using streptokinase. *Indian Heart Journal*. 2003;55(2):153-157.
 - Iqbal J, Serruys PW, Silber S, Kelbaek H, Richardt G, Morel MA, et al. Comparison of zotarolimus- and everolimus-eluting coronary stents: final 5-year report of the RESOLUTE all-comers trial. *Circulation: Cardiovascular Interventions*. 2015;8(6):e002230.
 - Bourguignon T, Bouquiaux-Stablo AL, Candolfi P, Mirza A, Loardi C, May MA, et al. Very long-term outcomes of the Carpentier-Edwards Perimount valve in aortic position. *The Annals of Thoracic Surgery*. 2015;99(3):831-837.
 - Goldstone AB, Chiu P, Baiocchi M, Lingala B, Patrick WL, Fischbein MP, et al. Mechanical or biologic prostheses for aortic-valve and mitral-valve replacement. *New England Journal of Medicine*. 2017;377(19):1847-1857.
 - Bourguignon T, El Khoury R, Candolfi P, Loardi C, Mirza A, Boulanger-Lothion J, et al. Very long-term outcomes of the Carpentier-Edwards Perimount aortic valve in patients aged 60 or younger. *The Annals of Thoracic Surgery*. 2015;100(3):853-859.
 - Isaacs AJ, Shuhaiber J, Salemi A, Isom OW, Sedrakyan A. National trends in utilization and in-hospital outcomes of mechanical versus bioprosthetic aortic valve replacements. *The Journal of Thoracic and Cardiovascular Surgery*. 2015;149(5):1262-1269.
 - Lengyel M, Fuster V, Keltai M, Roudaut R, Schulte HD, Seward JB, et al. Guidelines for management of left-sided prosthetic valve thrombosis: a role for thrombolytic therapy. *Journal of the American College of Cardiology*. 1997;30(6):1521-1526.
 - Puri D, Mahapatra AK, Premkumar M, Nayak B, Sahu M, Pande S, et al. Assessment of quality of anticoagulation control in patients with mechanical heart valves at a tertiary care center in Northern India. *Indian Heart Journal*. 2018;70(Suppl 3):S368-S373.
 - Nagaraja V, Chamberlain RS. Thrombotic and bleeding events after mechanical valve replacement: a comparison of anticoagulation regimens. *Brazilian Journal of Cardiovascular Surgery*. 2016;31(5):381-386.
 - Teshima H, Hayashida N, Yano H, Nishimi M, Tayama E, Fukunaga S, et al. Obstruction of St Jude Medical valves in the aortic position: histology and immunohistochemistry of pannus. *The Journal of Thoracic and Cardiovascular Surgery*. 2003;126(2):401-407.
 - Mylotte D, Osnabrugge RL, Windecker S, Lefèvre T, de Jaegere P, Jeger R, et al. Transcatheter aortic valve replacement in Europe: adoption trends and factors influencing device utilization. *Journal of the*

- American College of Cardiology. 2013;62(3):210-219.
22. Wang A, Athan E, Pappas PA, Fowler VG Jr, Olaison L, Pare C, et al. Contemporary clinical profile and outcome of prosthetic valve endocarditis. *JAMA*. 2007;297(12):1354-1361.
 23. Vogt PR, Brunner-LaRocca H, Lachat M, Rüter F, Künzli A, Turina MI. Reoperative surgery for degenerated aortic bioprostheses: predictors for emergency surgery and reoperative mortality. *European Journal of Cardio-Thoracic Surgery*. 2000;17(2):134-139.
 24. Karthikeyan G, Math RS, Mathew N, Shankar B, Kalaivani M, Singh S, et al. Accelerated infusion of streptokinase for the treatment of left-sided prosthetic valve thrombosis: a randomized controlled trial. *Circulation*. 2009;120(13):1108-1114.
 25. Noly PE, Emieux N, Bruneval P, Folkman V, Lanier JA, Paterson MT, et al. Evaluation of a new treatment algorithm for prosthetic valve thrombosis. *Journal of the American College of Cardiology*. 2020;75(17):2156-2166.