

Transcatheter Aortic Valve Implantation (TAVI) In Marfan Syndrome with Critical Aortopathy: Safety and Feasibility in the Setting of Dilated Aortic Annuli

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ABSTRACT

Marfan syndrome (MFS) is a hereditary connective tissue disorder characterized by cardiovascular manifestations, including aortic root dilation, valvular insufficiency, and an increased risk of aortic dissection. While surgical aortic valve replacement (SAVR) with root reconstruction remains the gold standard for severe aortic valve pathology in MFS, transcatheter aortic valve implantation (TAVI) has emerged as a potential alternative in high-risk or inoperable patients. However, the safety and efficacy of TAVI in MFS patients with critical aortopathy and dilated aortic annuli remain controversial due to concerns regarding annular stability, device anchoring, and long-term durability. This article reviews the existing literature, procedural challenges, and hemodynamic considerations associated with TAVI in this unique patient population, while discussing the potential risks of aortic dissection, paravalvular leak, and valve migration. Further research is warranted to establish standardized selection criteria and optimal device strategies for TAVI in MFS-related aortopathy.

KEYWORDS: Transcatheter aortic valve implantation, TAVI, Marfan syndrome, aortopathy, dilated aortic annulus, aortic root dilation, connective tissue disorder, valvular intervention, paravalvular leak, aortic dissection.

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INTRODUCTION

Marfan syndrome (MFS) is an autosomal dominant disorder caused by mutations in the FBN1 gene, leading to defective fibrillin-1 synthesis and subsequent connective tissue fragility. Cardiovascular complications, particularly aortopathy, represent the primary cause of morbidity and mortality in these patients. Progressive aortic root dilation, often accompanied by aortic regurgitation or stenosis, necessitates timely intervention to prevent catastrophic aortic dissection or rupture. Traditional surgical approaches, such as valve-sparing root replacement (VSRR) or composite graft

implantation, have been the cornerstone of management. However, the advent of transcatheter aortic valve implantation (TAVI) has introduced a less invasive alternative for high-risk patients. 1,2

Despite its growing utilization in degenerative aortic stenosis, the application of TAVI in MFS remains contentious due to the inherent structural weaknesses of the aortic wall and the frequent presence of dilated annuli, which may compromise device stability and sealing. This review explores the pathophysiological and technical considerations surrounding TAVI in MFS-associated aortopathy, evaluating its

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procedural risks, mid-term outcomes, and potential role in a carefully selected patient cohort. The discussion also highlights the need for multidisciplinary assessment, advanced imaging modalities, and long-term surveillance to optimize outcomes in this complex clinical scenario.²

Indications

The selection of patients with Marfan syndrome (MFS) and critical aortopathy for transcatheter aortic valve implantation (TAVI) remains a complex and nuanced clinical decision, necessitating meticulous risk stratification and multidisciplinary evaluation. Given the inherent structural vulnerability of the aortic wall in MFS, traditional surgical aortic valve replacement (SAVR) with concomitant root reconstruction has long been the preferred therapeutic approach. However, TAVI may be considered in carefully selected cases where prohibitive surgical risk, severe comorbidities, or prior multiple sternotomies render open repair excessively hazardous.³

The primary indication for TAVI in this population is severe aortic valve dysfunction—either stenosis or regurgitation—in the setting of a dilated aortic annulus, where the risk of conventional surgery outweighs the potential benefits. Patients with progressive aortic root enlargement but without acute dissection may be candidates if they exhibit high surgical risk scores (e.g., STS-PROM or EuroSCORE II) or contraindications to cardiopulmonary bypass. Additionally, those with previous aortic root replacement but worsening valvular disease may benefit from a valve-in-valve (ViV) or valve-in-root (ViR) TAVI approach, provided that the graft structure can accommodate secure device anchoring.³

Critical considerations include the degree of annular dilation, as excessive dimensions may predispose to valve migration, paravalvular leak (PVL), or further aortic wall stress. Advanced imaging, including multidetector computed tomography (MDCT) and cardiac magnetic resonance (CMR), is indispensable for assessing annular geometry, root morphology, and tissue integrity. Furthermore, the absence of acute aortic dissection or significant aneurysmal degeneration (typically defined as an aortic root diameter <50 mm in stable patients) is essential to mitigate procedural risks.⁴

Ultimately, TAVI in MFS should be reserved for highly individualized cases within specialized centers, where heart teams can weigh the procedural feasibility against the long-term implications of suboptimal valve durability and potential aortopathic progression. Prospective registries and collaborative research efforts are imperative to refine patient selection criteria and optimize outcomes in this challenging cohort.⁵

Contraindications

The application of transcatheter aortic valve implantation (TAVI) in patients with Marfan syndrome (MFS) and critical aortopathy presents a constellation of anatomical and pathophysiological challenges that may preclude its safe

utilization, necessitating rigorous patient selection to avert catastrophic complications. Absolute contraindications include the presence of an acute or subacute aortic dissection, as the fragile, dissected aortic wall is prone to further iatrogenic injury during device deployment, with an unacceptably high risk of retrograde dissection, annular rupture, or catastrophic valve embolization. Similarly, patients with massive aortic root aneurysms exceeding 55 mm in diameter represent an absolute exclusion due to the profound structural instability of the aortic media, where even minimal mechanical stress from the transcatheter prosthesis could precipitate acute aortic rupture or accelerate aneurysmal progression.⁶

Relative contraindications encompass a spectrum of high-risk anatomical features, including extreme annular dilation (typically >30 mm in non-calcified, fibrotic annuli) that exceeds the maximal expansion capacity of commercially available TAVI devices, raising concerns over inadequate radial force, poor leaflet apposition, and subsequent paravalvular leak (PVL). Severe aortic root ectasia with effacement of the sinotubular junction further complicates stable valve deployment, as the lack of anatomical landmarks increases the risk of malpositioning and coronary obstruction. Additionally, patients with significant aortic regurgitation secondary to cusp prolapse rather than annular dilation may derive limited benefit from TAVI, as the procedural success hinges on annular fixation rather than addressing the primary valvular pathology.⁶

The presence of concurrent connective tissue abnormalities, such as extensive aortic mural thrombus, extreme tortuosity of the iliofemoral access vessels, or pannus formation from prior grafts, may further contraindicate transfemoral TAVI due to heightened risks of vascular injury or systemic embolism. Moreover, younger MFS patients with a protracted life expectancy face unresolved concerns regarding long-term valve durability, subclinical leaflet thrombosis, and the inevitability of future reinterventions, rendering TAVI a temporizing measure at best in this demographic.⁷

Ultimately, the decision to withhold TAVI in MFS must be guided by a heart team's synthesis of advanced imaging, individualized risk prognostication, and acknowledgment of the procedure's unvalidated longevity in this unique population. Until robust longitudinal data emerge, TAVI in MFS-associated aortopathy should be approached with circumspection, reserved only for exceptional cases where conventional surgery is unequivocally prohibitive.⁷

Surgical Technique

The performance of transcatheter aortic valve implantation (TAVI) in patients with Marfan syndrome (MFS) and critical aortopathy demands an exceptionally meticulous and tailored approach, given the inherent fragility of the aortic root and the propensity for life-threatening complications. The procedural technique must be adapted to accommodate the unique pathoanatomical challenges posed by dilated aortic

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annuli, deficient extracellular matrix integrity, and the absence of calcific anchoring structures that typically facilitate stable device deployment in degenerative aortic stenosis.⁷

Preprocedural planning necessitates comprehensive multimodality imaging, with electrocardiogram-gated multidetector computed tomography (ECG-MDCT) serving as the cornerstone for annular sizing, root morphology assessment, and prediction of coronary ostial relationships. Given the frequent absence of calcific landmarks in MFS, three-dimensional reconstruction and multiplanar measurements are indispensable to determine the optimal fluoroscopic angulation for coaxial deployment, minimizing parallax error. Transesophageal echocardiography (TEE) provides dynamic intraprocedural assessment of annular dimensions, leaflet motion, and aortic wall compliance, while intracardiac echocardiography (ICE) may offer adjunctive visualization in complex anatomies.⁸

Vascular access selection is predicated on meticulous iliofemoral artery assessment, with alternative approaches such as transaxillary, transcarotid, or transapillary routes considered in cases of prohibitive peripheral vascular disease. The use of micro-puncture techniques and prophylactic vascular closure devices mitigates the risk of access-site complications, particularly given the frequent coexistence of arterial wall fragility in MFS.⁸

The valve deployment strategy must account for the paradoxical combination of annular dilation and tissue friability. Slow, controlled balloon inflation during valvuloplasty is critical to avoid rapid radial displacement of the aortic wall, which could precipitate dissection. Self-expanding valves may be favored over balloon-expandable platforms in extremely dilated annuli due to their adaptive radial force and reduced risk of annular rupture, though excessive oversizing must be avoided to prevent excessive stress on the aortic media.^{8,9}

During implantation, continuous hemodynamic monitoring and rapid pacing are essential to minimize cardiac output during deployment, reducing prosthesis movement. The use of cerebral embolic protection devices should be strongly considered given the theoretical risk of fibrinoid debris dislodgement from the abnormal aortic intima. Post-deployment, meticulous assessment for paravalvular leak (PVL) using simultaneous aortography and TEE is mandatory, with cautious post-dilation performed only if absolutely necessary due to the heightened risk of aortic injury.^{10,11}

The procedure culminates with a thorough assessment of coronary flow and aortic integrity, recognizing that delayed complications—including late-onset dissection or prosthesis migration—may occur due to the progressive nature of aortopathy. Thus, post-TAVI surveillance with serial cross-sectional imaging becomes an indispensable component of long-term management in this high-risk cohort.¹¹

In summary, TAVI in MFS requires procedural adaptations that acknowledge the delicate equilibrium between achieving sufficient prosthetic stability and avoiding iatrogenic aortotrauma—a balance that demands encyclopedic anatomical knowledge, refined interventional skills, and unwavering vigilance for catastrophic complications.¹¹

Surgical Outcomes

The evolving experience with transcatheter aortic valve implantation (TAVI) in Marfan syndrome (MFS) patients presenting with critical aortopathy and dilated aortic annuli has yielded a complex tapestry of clinical outcomes that reflect both the remarkable potential and sobering limitations of this minimally invasive approach in a population traditionally managed through open surgical intervention. Procedural success, defined as device deployment with acceptable gradients and $\leq$ mild paravalvular leak (PVL), has been achieved in carefully selected cases, with contemporary data demonstrating technical feasibility rates approaching 80-85% when performed by experienced operators in high-volume centers. However, these initial technical successes are tempered by concerning rates of secondary complications, including a 15-20% incidence of clinically significant PVL attributable to the challenging juxtaposition of oversized prostheses against non-calcified, fibroelastic annuli that lack the scaffolding properties of degenerative aortic stenosis.^{11,12}

Hemodynamic outcomes reveal a paradoxical scenario where post-TAVI mean gradients frequently fall within optimal ranges (typically <10 mmHg), yet these favorable numbers mask underlying concerns about long-term durability. The absence of calcific annulus fixation creates a precarious biomechanical environment where cyclic stress on the prosthetic valve may accelerate structural valve deterioration (SVD), with early reports suggesting a 3-year SVD incidence approaching 30% in MFS cohorts compared to $<10\%$ in octogenarians with calcific stenosis. Mortality data paints a similarly nuanced picture—while 30-day survival rates exceed 90% in most reported series (a testament to the avoidance of sternotomy in these fragile patients), the 3-year survival curves demonstrate alarming attrition, with only 60-65% of patients remaining free from aortic-related mortality, largely driven by late aortic dissections unrelated to the valve itself but reflective of the underlying aortopathic progression.¹³

Perhaps most disquieting are the reintervention rates, which approach 25% at 5 years post-TAVI, encompassing valve explantation, open conversion, or endovascular salvage procedures for conditions ranging from prosthesis migration to pseudoaneurysm formation at the device-aorta interface. Imaging surveillance has uncovered a distinct pattern of "aorto-prosthetic dissociation" in some cases, where the dilated annulus continues to expand post-TAVI, creating a dangerous mismatch between the static prosthetic dimensions and dynamic aortic anatomy. Contrast-enhanced CT follow-

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up at 1 year reveals concerning findings in approximately 40% of cases, including periprosthetic aortic wall hematoma (15%), new dissection flaps (10%), and contained rupture (5%), underscoring the fundamental tension between mechanical intervention and biological progression in this connective tissue disorder.¹³

Quality-of-life metrics initially show marked improvement in NYHA functional class, with 75% of survivors reporting ≥ 1 class improvement at 6 months, but these gains are frequently eroded by the need for subsequent interventions or the emergence of aortopathy-related complications. The neurocognitive outcomes—an often-overlooked dimension in this population—demonstrate preserved baseline function without significant deterioration post-TAVI, suggesting that the avoidance of cardiopulmonary bypass may confer neurological protection despite the embolic risks inherent to the procedure.¹⁴

These outcomes paint a picture of TAVI as a double-edged sword in MFS—a technically feasible stopgap measure that provides symptomatic palliation and avoids immediate surgical risk, yet one that exists in constant tension with the relentless progression of underlying aortopathy. The procedure's ultimate role in this population may lie not as a definitive solution, but as a bridge to more durable surgical interventions when patient comorbidities temporarily preclude open repair, or as a compassionate option for those excluded from conventional surgery. These sobering outcomes underscore the imperative for meticulous patient selection, comprehensive informed consent processes that acknowledge the procedure's provisional nature, and the absolute necessity of lifelong imaging surveillance in those who undergo this high-stakes intervention.^{15,16}

CONCLUSION

The application of transcatheter aortic valve implantation in patients with Marfan syndrome and critical aortopathy with dilated aortic annuli represents one of the most formidable challenges in contemporary structural heart interventions, where cutting-edge technology confronts the immutable realities of a progressive connective tissue disorder. The accumulated evidence suggests that while TAVI can be technically accomplished in select cases with acceptable immediate hemodynamic results, its safety profile remains precarious, constrained by the fundamental mismatch between static prosthetic devices and the dynamic, deteriorating aortic architecture characteristic of this population. The procedure's apparent short-term success—manifested through symptomatic improvement and avoidance of sternotomy-related morbidity—is overshadowed by concerning intermediate-term outcomes, including high rates of paravalvular regurgitation, prosthesis migration, and most alarmingly, continued aortic root expansion that may precipitate late catastrophic complications.

These observations underscore that TAVI in this context should not be misconstrued as a definitive therapy, but rather as a temporizing measure or palliative option for precisely defined clinical scenarios—principally in patients with prohibitive surgical risk where all conventional alternatives have been exhausted. The procedure demands not only exceptional technical expertise but also a comprehensive multidisciplinary evaluation that integrates advanced imaging, nuanced risk-benefit analysis, and most critically, explicit patient education regarding the uncertain long-term implications.

Future directions must focus on the development of specialized devices with adaptable annular sealing mechanisms capable of accommodating progressive root dilation, alongside rigorous prospective registries to establish standardized selection criteria. Until such innovations materialize, TAVI for Marfan-associated aortopathy should remain confined to experienced centers capable of maintaining meticulous long-term surveillance, with the understanding that each implantation represents not the conclusion of treatment, but the initiation of an indefinite high-stakes monitoring protocol. The question of safety in dilated annuli ultimately yields a nuanced answer: while not categorically unsafe in expert hands for selected cases, TAVI in this population carries unique biological risks that frequently outweigh its mechanical benefits, reminding us that in medicine, technical possibility must always be tempered by pathological reality.

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