Review Article

Transcatheter Aortic Valve Replacement: Review Article

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Abstract

Over the past two decades, the field of transcatheter aortic valve replacement (TAVR) has undergone significant advancement, driven by both technological innovation and procedural refinement. Once a procedure that was conducted under general anesthesia in an operating room followed by a 5+-day hospital stay is now predominantly being done using moderate sedation in a catheterization laboratory, with many patients being discharged home the following day. Several factors have contributed to this transformation. These include the expansion of TAVR to lower-risk patient populations, reductions in delivery system size facilitating broader use of transfemoral access, and the implementation of streamlined care pathways such as the 3M approach—multidisciplinary, multimodality, but minimalist. This minimalist strategy has been pivotal in enhancing procedural efficiency and reducing resource utilization without compromising outcomes. As a result, TAVR volumes have grown exponentially in recent years and are expected to continue rising, particularly as the procedure is investigated for new indications such as moderate aortic stenosis and asymptomatic severe aortic stenosis. Central to the success of TAVR is a comprehensive assessment of each patient's suitability for valve replacement, performed by a multidisciplinary heart valve team.

Key Wards: aortic stenosis, transcatheter aortic valve replacement, current situation.

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Introduction

Aortic stenosis (AS) is recognized as the most prevalent valvular heart disease in developed nations [1]. The most common etiology is age-associated calcific degeneration of the aortic valve and less likely rheumatic heart disease [2,3]. The prevalence of AS increases with advancing age, affecting approximately 2.8% of individuals aged 60-74 years and rising to 13.1% in those aged 75 years or older-amounting to an estimated 16.1 million cases worldwide [4]. The stenotic aortic valve increases the ventricular afterload, leading to initial compensatory left ventricular hypertrophy and eventual progression to left-sided heart failure, if not treated [5]. Prognosis in patients with severe symptomatic AS managed conservatively is poor, with an estimated 50% mortality rate within one year [5]. Traditionally, surgical aortic valve replacement (SAVR) has served as the definitive treatment for severe AS. Its key advantages include well-established procedure, favorable long-term outcomes, lower risk of prosthesis-patient mismatch, absence of paravalvular regurgitation, and suitability in patients with anatomically small aortic roots. Disadvantages of SAVR are: invasive procedure, required general anesthesia, longer recovery time, higher risk of complications, not suitable for all patients.

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However, over the past two decades, the advent of transcatheter aortic valve replacement (TAVR) has revolutionized the management of patients with severe AS. Randomized controlled trials (RCT) have demonstrated the safety and efficacy of TAVR, first in inoperable, and then in high-risk, intermediate, low-risk and most recently asymptomatic patients [6,7].In particular, the paradigm shift from a symptomatic to a "asymptomatic" severe AS represents one of the major challenges of modern cardiology, radically changing the decision-making process in the treatment of valvular heart diseases [8]. TAVR offers several benefits: it is less invasive, allows for faster post-procedural recovery, lower risk of some complications, is well suited for high-risk patients, and may offer survival advantages in certain groups [6]. Nonetheless, TAVR is associated with certain drawbacks, including concerns about long-term valve durability, a higher incidence of paravalvular regurgitation, increased likelihood of requiring permanent pacemaker implantation, as well as risks of stroke and vascular complications [6]. Additionally, it tends to be more expensive than SAVR [6].

More recently, there has been a resurgence of interest in minimally invasive aortic valve replacement (miAVR) for appropriately selected patients [9]. This technique utilizes smaller surgical incisions- such as a mini-sternotomy or right anterior mini-thoracotomy- in contrast to the full median sternotomy used in conventional surgery [10].

Emerging evidence suggests that miAVR can offer favorable outcomes, including reduced blood loss, shorter durations in intensive care, and lower rates of acute kidney injury (AKI) and perioperative mortality [11,12]. Despite these advantages, miAVR is not without challenges. It typically involves longer cardiopulmonary bypass and aortic cross-clamp times, which may elevate the risk of adverse intraoperative and postoperative outcomes [13–15]. Compared to TAVR, miAVR enables direct surgical visualization of the aortic valve, removal of extensive annular calcification, and a lower incidence of paravalvular regurgitation [16]. However, these benefits may come at the expense of extended hospital stays and an increased risk of AKI [17].

First Human Reports

The first successful transcatheter aortic valve replacement (TAVR) was carried out on April 16, 2002, by Cribier and colleagues, marking a pivotal moment in the management of structural heart disease [18]. The procedure was performed on a 57-year-old patient with severe symptomatic aortic stenosis (AS) who had previously undergone balloon aortic valvuloplasty. Unfortunately, the patient's condition worsened within a week due to recoil of the stenotic valve, resulting in hemodynamic instability. Given the critical nature of the situation and the patient's inoperability, a percutaneous valve was implanted using an antegrade approach via the right femoral vein. Following the TAVR procedure, the patient's clinical status improved significantly within hours, allowing for early mobilization. Hemodynamic assessment over the subsequent nine weeks showed excellent valve function and performance. However, at four months post-procedure, the patient passed away because of noncardiac or procedure-related causes [19].

First Clinical Studies

The Initial Registry of Endo Vascular Implantation of Valves in Europe (I-REVIVE) and the Registry of Endovascular Critical Aortic Stenosis Treatment (RECAST) were among the earliest studies to assess the feasibility and safety of TAVR in clinical practice [20,21]. In these initial registries, the majority of procedures were performed using the antegrade transvenous approach. The procedural success rate reported was approximately 75%, while the overall complication rate stood at 22%. Patients who underwent uncomplicated and successful TAVR demonstrated a notable improvement in their symptoms. However, their long-term prognosis remained poor, with a major adverse cardiovascular event (MACE) rate of 37% at six months. This unfavorable outcome was largely attributed to the high burden of comorbidities present in this early, high-risk patient population.

Evidence from Randomized Control Trials

The Placement of Aortic Transcatheter Valves (PARTNER) Cohort B trial was the first randomized controlled study to evaluate the prognostic impact of TAVR in inoperable patients. The findings demonstrated a significant survival benefit in the TAVR group compared to those receiving standard therapy, which included medical management alone or combined with balloon aortic valvuloplasty. At one year, the mortality rate was 20.5% in the TAVR group, compared to 44.6% in the control group, underscoring the potential of TAVR to substantially improve outcomes in this high-risk population [22]. A year later, the PARTNER Cohort A trial was conducted, comparing the efficacy and safety of TAVR versus surgical aortic valve replacement (SAVR) in patients at high surgical risk [23]. The study found no significant differences in all-cause mortality at both 1-year (24.2% for TAVR vs. 26.8% for SAVR) and 2-year follow-up (33.9% vs. 35.0%). However, there were notable differences in complication profiles: patients undergoing TAVR experienced a higher incidence of neurological events (11.2% vs. 6.5%) and major vascular complications (11.6% vs. 3.8%), whereas those treated with SAVR had a greater risk of major bleeding (29.5% vs. 19%) at 2 years.

The PARTNER 2 Cohort A trial extended the evaluation to patients at intermediate surgical risk, reporting 5-year outcomes on clinical endpoints, valve function, and health-related quality of life [24]. Results showed no significant difference in the combined endpoint of death or disabling stroke between the TAVR and SAVR groups (47.9% vs. 43.4%). Additionally, improvements in health status at 5 years were comparable between the two interventions. The PARTNER 3 trial showed that the rate of the composite end point of death, stroke, or re-hospitalization at 1 and 2 years was significantly lower with TAVR than with surgery [25-27]. Five-year follow-up of the PARTNER 3 trial reported the incidence of the composite end point of death, stroke, or re-hospitalization was similar in the TAVR group and the surgery group; the incidence of the individual components of the primary end points (including death from any cause, disabling stroke, non-disabling stroke, and re-hospitalization) was also similar in the two groups [28].

The Evaluation of TAVR Compared to Surveillance for Patients with Asymptomatic Severe Aortic Stenosis (EARLY TAVR) trial reported among patients with asymptomatic severe aortic stenosis, a strategy of early TAVR was superior to clinical surveillance in reducing the incidence of death, stroke, or unplanned hospitalization for cardiovascular causes [7].

Current guideline recommendations for TAVR

Both the American College of Cardiology/American Heart Association (ACC/AHA) [29] and European Society of Cardiology (ESC) [30] guidelines for the management of patients with valvular heart disease have been updated and provide recommendations for TAVR (Table 1).

Table 1. Current indications of TAVR.

2020 ACC/AHA Guidelines [29]	2021 ESC Guidelines [30]
Transfemoral TAVR is recommended over SAVR in patients aged >80 years or in younger patients with a life expectancy <10 years and no anatomic contraindication to transfemoral TAVR (Class IA)	TAVR is recommended in older patients with age >75 years or those at high risk (STS PROM/EuroSCORE II > 8%) or unsuitable for surgery (Class IA)
TAVR is recommended for patients with symptomatic severe AS aged 65–80 years and no anatomic contraindication to transfemoral TAVR (Class IA)	SAVR or TAVR is recommended for remaining patients after taking into account of patient's clinical, anatomic, and procedural characteristics (Class IB)

However, the clinical decision between TAVR vs. SAVR requires the consideration of multiple and complex clinical and anatomical factors (Table 2) [30].

Table 2. Clinical, anatomical and procedural factors thatinfluence the choice of treatment modality for an individual patient

	Favours TAVR	Favours SAVR
Clinical characteristics		
Lower surgical risk	-	+
Higher surgical risk	+	-
Younger age[a]	-	+
Older age[a]	+	-
Previous cardiac surgery (particularly intact coronary artery bypass grafts at risk of injury during repeat sternotomy)	+	-
Severe frailty[b]	+	-
Active or suspected endocarditis	-	+
Anatomical and procedural factors		
TAVI feasible via transfemoral approach	+	-
Transfemoral access challenging or impossible and SAVR feasible	-	+[c]
Transfemoral access challenging or impossible and SAVR inadvisable	+	-
Sequelae of chest radiation	+	-
Porcelain aorta	+	-
High likelihood of severe patient prosthesis mismatch (AVA <0.65 cm^2/m^2 BSA)	+	-
Severe chest deformation or scoliosis	+	-
Aortic annular dimensions unsuitable for availableTAVI devices	-	+
Bicuspid aortic valve	-	+
Valve morphology unfavourable for TAVI (e.g.high risk of coronary obstruction due to low coronary ostia or heavy leaflet/LVOTcalcification)	-	+
Thrombus in aorta or LV	-	+
Concomitant cardiac conditions requiring intervention		
Significant multi-vessel CAD requiring surgical revascularization[d]	-	+
Severe primary mitral valve disease	-	+
Severe tricuspid valve disease	-	+
Significant dilatation/aneurysm of the aortic root and/or ascending aorta	-	+
Septal hypertrophy requiring myectomy	-	+

AVA = aortic valve area, BSA = body surface area, CAD= coronary artery disease; ESC = European Society of Cardiology; LV = left ventricle/left ventricular;LVOT = left ventricular outflow tract; SAVR = surgical aortic valve replacement;TAVI = transcatheter aortic valve implantation.
Integration of these factors provides guidance for the Heart Team decision (indicationsfor intervention are provided in the table of recommendations on indicationsfor intervention in symptomatic and asymptomatic aortic stenosis andrecommended mode of intervention).

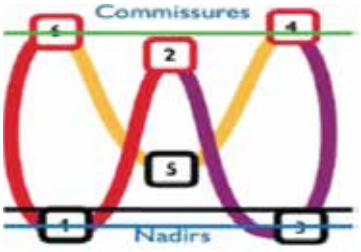
a Life expectancy is highly dependent on absolute age and frailty, differs betweenmen and women, and may be a better guide than age alone. There is wide variationacross Europe and elsewhere in the world (http://ghdx.healthdata.org/record/ihme-data/gbd-2017-life-tables-1950-2017).
b Severe frailty = >2 factors according to Katz index.
c Via non-transfemoral approach.
d According to the 2019 ESC Guidelines for the diagnosis and management ofchronic coronary syndromes.

Pre-procedure evaluation of TAVR

A thorough preprocedural evaluation is critical for minimizing complications during transcatheter aortic valve replacement (TAVR) and for appropriate risk stratification of patients. It involves a detailed assessment of both cardiac and non-cardiac comorbidities prior to intervention [31]. A multidisciplinary heart team plays an essential role in selecting suitable candidates, planning the procedure, and executing it safely [32]. For anatomical assessment of the aortic valve and surrounding structures, imaging modalities such as two- and three-dimensional transthoracic echocardiography (TTE), transesophageal echocardiography (TEE), ECG-gated multidetector computed tomography (MDCT), and, in select cases, cardiac magnetic resonance imaging (CMR) are employed [32]. These modalities provide complementary information that is crucial for accurate valve sizing and transcatheter heart valve (THV) selection. Among them, TTE, TEE, and MDCT are considered the primary imaging tools for evaluating aortic root anatomy [32].

The aortic valve complex includes several key anatomical structures: the aortic annulus, valve commissures, sinuses of Valsalva (SOV), coronary ostia (CO), and the sinotubular junction (STJ). The three aortic cusps attach proximally to the left ventricular outflow tract (LVOT) at their nadir points, also known as hinge points [33]. Connecting these nadirs forms the "virtual basal ring", an oval, crown-like structure that defines the aortic annulus (Figure1). This annular plane is double oblique and does not align with standard MDCT planes (axial, coronal, or sagittal), making dedicated reconstructions necessary for accurate measurement. This ring is the major target for transcatheteraortic valve prosthesis sizing [32].

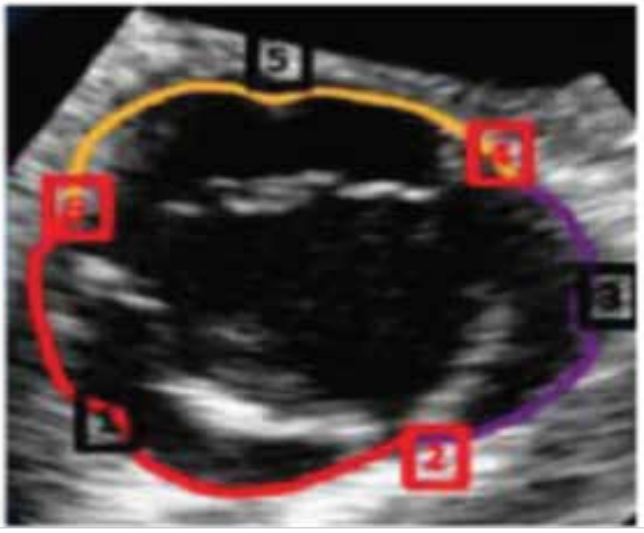
The distal attachment of the three semilunar cusps occurs at the level of the surgical annulus, which aligns with the sinotubular junction (STJ)—the anatomical transition between the sinuses of Valsalva (SOV) and the ascending aorta. To accurately visualize the virtual basal ring, which serves as the reference plane for TAVR prosthesis sizing, extensive post-processing of raw imaging data is often necessary. This virtual basal ring is often not orthogonal to the LVOT, and insertion of the right coronary cusp can often be inferior to the left and non-coronary cusps [34].



A. Virtual basal ring

Blue-basal ring, or aortic annulus
Black-anatomic ventriculo-arterial junction
Green-surgical annulus, corresponds to STJ
Red-right coronary cusp annulus
Purple-left coronary cusp annulus
Yellow-non coronary cusp

STJ-sinotubular junction



B. TEE-2D aortic short axis view

Figure 1: Aortic valve complex: schematic representation and correlation with transesophageal echocardiography (TEE) [32].

Echocardiography

The initial evaluation of aortic stenosis typically begins with TTE, which provides key information regarding stenosis severity, leaflet mobility, annular dimensions, and the extent of calcification [31]. During the TAVR procedure, TEE plays a vital intra-operative role by offering real-time imaging, assisting in precise device deployment, and helping to evaluate for aortic regurgitation [22]. TEE is also valuable for identifying serious intra-procedural complications such as pericardial tamponade, aortic dissection, left ventricular injury, mitral regurgitation, and valve embolization [22].

However, both echocardiography and angiography have limitations, particularly in accurately characterizing the non-circular (often oval-shaped) geometry of the aortic

annulus [32]. Specifically, 2D echocardiography has been shown to underestimate the mean annular diameter by approximately 1 ± 1.7 mm [32]. The role of TEE for TAVR preoperative assessment has been diminished by the advent of CT [31]. TTE can be supplemented with ECG-gated multidetector computed tomography (MDCT) during pre-procedural TAVR planning, to provide a three-dimensional anatomical assessment [31].

Coronary angiography

Coronary angiography remains the gold standard for assessing coronary artery disease (CAD) in patients undergoing evaluation before TAVR [35]. However, the use of coronary computed tomography angiography (CCTA) is becoming more widespread in this context [35]. CCTA offers a non-invasive alternative to traditional angiography and demonstrates a high negative predictive value (NPV), making it useful for ruling out significant CAD [35]. Despite its advantages, CCTA has certain limitations—particularly in patients with heavily calcified coronary vessels or previous stent placements, as these can result in false-positive findings, reducing the accuracy in determining lesion severity [35]. In such cases, invasive coronary angiography is typically required to confirm and further characterize coronary lesions identified on CCTA [35]. While CCTA presents a convenient and less invasive option, it is best suited for carefully selected patients with a low pretest probability of CAD to minimize diagnostic uncertainty [35].

MDCT

The Society of Cardiac Computed Tomography (SCCT) recommends using at least a 64-slice CT scanner for MDCT imaging prior to TAVR, with higher-slice scanners such as 128, 256, or 320-slice systems offering advantages including shorter acquisition times and reduced contrast volume [32,34]. A high-pitch spiral dual-source CT angiography protocol is also favored to enhance image quality and speed [36]. Imaging should be conducted with the patient in the supine position during breath-hold to minimize motion artifacts [34]. For accurate evaluation of the aortic valve annulus and root, ECG-gated CT angiography is performed with either prospective or retrospective ECG triggering, capturing the ascending aorta and heart [32]. It has been demonstrated that imaging during systole is preferable over diastole due to the larger annular dimensions and the dynamic changes observed during this phase of the cardiac cycle [37,38]. Routine administration of β-blockers for scan optimization is generally avoided because of concerns regarding the underlying severe aortic stenosis [32].

Before TAVR, MDCT is the imaging modality of choice for assessing: (i) aortic valve anatomy, (ii) annulus size and shape, (iii) extent and distribution of calcification in the valve and vasculature, (iv) risk of coronary ostial obstruction, (v) dimensions of the aortic root, (vi) optimal fluoroscopic angles for valve deployment, and (vii) the feasibility of vascular access routes such as femoral, subclavian, axillary, carotid, transcaval, or transapical approaches [30]. Measurements of the aortic valve and qualitative assessments are performed on properly reconstructed images to ensure accuracy [32]. Three key measurements are particularly informative for annular sizing and prosthesis selection (Table 3): (1) The long and short diameters of the aortic annulus, with the mean diameter calculated as their average [39]; (2) The circumference (perimeter) of the annulus, which can be manually traced or calculated assuming a circular shape; (3) The aortic annulus area, obtained either from the mean diameter or via manual planimetry on reconstructed images [32].

Table 3. Aortic valve apparatus/ascending aorta measurements pertinent for TAVR

Aortic annulus (AA) (virtual basal ring)
• AA maximal diameter
• AA perpendicular minimal diameter
• AA average diameter
• AA cross-sectional area (CSA)
• AA circumference
Aortic valve
• Cuspidity
• Comissure calcifications
• Aortic annulus calcifications
• Severely calcified cusp that might compromise coronary the artery ostia: yes/no
Ascending aorta
• Width at 40 mm from the annulus
• Position relative to the sternum
Sinuses of Valsalva
• Maximum diameter
• Height
• Sinotubular junction maximum diameter
• Distance from the aortic annular plane to the coronary artery ostia

Cardiac MRI (CMR)

Non-contrast cardiac magnetic resonance (nc-CMR) has emerged as a reliable and safe imaging alternative for evaluating the aortic valvular complex in patients undergoing TAVR who have kidney dysfunction, where contrast administration is not feasible [40]. Both CMR and CT have demonstrated superiority in characterizing the elliptical configuration of the aortic annulus and root, and their routine use prior to TAVR has been associated with a reduced risk of significant post-procedural aortic regurgitation [41–43]. In addition, CMR provides important diagnostic information on the severity of aortic valve disease, including stenosis, regurgitation, or mixed pathology [44]. For patients with low-flow, low-gradient aortic stenosis, CMR—particularly when combined with dobutamine stress testing—can accurately assess valvular

severity along with right and left ventricular volumes and systolic function [45]. However, one limitation of CMR is its reduced accuracy in evaluating peripheral vasculature such as the iliofemoral arteries, particularly in the presence of heavy vascular calcification [46].

Procedure

Once the appropriate patient and prosthesis are selected, transcatheter aortic valve replacement (TAVR) is typically performed in five main steps: vascular access, valve crossing, balloon aortic valvuloplasty (BAV), valve deployment, and access site closure. Additional procedural considerations include the choice of anesthesia—conscious sedation versus general anesthesia—and placement of a temporary right ventricular pacing wire. Depending on vascular anatomy, the procedure can be performed via transfemoral, transaortic, or transapical access. In transfemoral procedures conscious sedation is preferably used; otherwise (in the initial femoral, direct aortic or transapical approach) general anaesthesia is instituted [47].

1. Vascular Access

Transfemoral approach: When feasible, the transfemoral route is the preferred option, associated with shorter procedural time, quicker recovery, and better clinical outcomes compared to the transapical approach, although baseline patient characteristics may influence these comparisons [48]. Initially, large-bore sheaths necessitated surgical cut-down; however, modern low-profile devices allow for fully percutaneous procedures. Alternative access routes are considered when iliofemoral anatomy is unsuitable—for example, luminal diameters <5.5 mm or significant tortuosity [49].

Transapical approach: This technique involves a limited left thoracotomy with direct entry through the left ventricular apex, thereby avoiding navigation of large delivery systems through the iliofemoral vessels and aortic arch. Its main drawbacks include the need for general anesthesia, higher myocardial injury risk, and prolonged recovery. Emerging "percutaneous" transapical techniques utilizing ventricular closure devices remain investigational and require further validation [49].

Transaortic approach: Access through a mini-sternotomy or right thoracotomy enables direct cannulation of the ascending aorta, avoiding both the iliofemoral vessels and left ventricular apex. Since aortic cannulation is a familiar technique to surgeons, this method offers a practical alternative in selected patients.

Other approaches: Alternative access routes such as transsubclavian, transaxillary, and transcaval access have been shown to be clinically effective in cases where conventional access is unsuitable [49].

2. Valve Crossing & 3. Balloon Aortic Valvuloplasty

Crossing the aortic valve is performed using an AL-1 catheter over a guidewire, typically in the left anterior oblique projection to minimize inadvertent entry into the left main coronary artery. If unsuccessful, alternative catheters (e.g., AR-1, JR-4) may be used. Hemodynamic assessment is performed before valve delivery, with particular attention to peak-to-peak systolic gradients and end-diastolic separation, the latter being useful for evaluating post-implant paravalvular regurgitation. A stiff guidewire is positioned in the left ventricle under fluoroscopic guidance for stability during valve delivery. Pre-implantation BAV, usually performed with rapid right ventricular pacing, helps prepare the stenotic valve for prosthesis deployment, with balloon sizing based on the minor annular diameter.

4. Valve Implantation

Alignment:

The delivery system is advanced over the guidewire to the aortic annulus under fluoroscopic guidance. Particular care is taken in calcified or angulated anatomies to avoid excessive force that may cause complications. Proper orientation is confirmed with a coplanar fluoroscopic projection.

Deployment:

Valve release is performed gradually, with continuous fluoroscopic and hemodynamic monitoring. Rapid ventricular pacing may be employed to stabilize the valve in patients with large annuli, hypertension, or aortic regurgitation. Deployment is continued carefully until annular contact and hemodynamic recovery is achieved, avoiding advancement beyond the "point of no recapture." Final positioning is confirmed using angiography and echocardiography. Once released, the system is withdrawn under wire protection, and repeat pressure tracings and imaging confirm valve function and the absence of significant paravalvular leak.

5. Closure

The large-bore sheath is removed, and percutaneous closure is achieved with vascular closure devices such as ProGlide® or Angio-Seal™. Protamine is administered to reverse anticoagulation if necessary. A completion angiogram is performed to confirm vascular integrity before finalizing closure at the alternate access site [49].

Current TAVR Devices

With the global expansion of TAVR, multiple transcatheter heart valves (THVs) and newer iterations have been introduced. THVs are primarily classified by their expansion mechanism: self-expanding valves (SEVs), balloon-expandable valves (BEVs), and mechanically expandable valves (MEVs) [50].

- SEVs:Evolut FX (Medtronic, USA), Acurate Neo2 (Boston Scientific, USA), Portico (Abbott, USA), Hydra (Sahajanand Medical, India), Venus-A

(Venus Medtech, China), VitaFlow (MicroPort, China), TaurusOne (Peijia Medical, China), Allegra (NVT, Germany), Trilogy (JenaValve, Germany), and J-Valve (JC Medical, USA).
- BEVs:Sapien 3, Sapien 3 Ultra, Sapien 3 Ultra Resilia (Edwards Lifesciences, USA), MyVal and MyValOctacor (Meril, India), and DurAVR (Anteris Technologies, Australia).
- MEVs: Lotus and Lotus Edge (Boston Scientific, USA) [50].

Early-generation devices such as SAPIEN and CoreValve demonstrated good efficacy but were associated with notable complications. To improve safety and performance, newer-generation THVs have been developed, including Portico, Lotus, Acurate TA/Neo, Direct Flow, SAPIEN XT/3/3 Ultra, CENTERA, JenaValve, Evolut series, Engager, MyVal, and Allegra [51].

Complications

Although TAVR has proven efficacy in treating aortic stenosis, it carries several potential complications. These include prosthesis dysfunction (malpositioning, paravalvular leak), vascular access injury, conduction disturbances, stroke, coronary overlap, prosthesis embolization, mitral valve disruption, and hemorrhage—all of which may increase hospital stay and readmission rates [32,50]. Rare but serious complications (0.2–1.1%) involve the aorta (dissection, perforation), aortic root (rupture), or left ventricle (perforation) [52].

Prosthesis dysfunction

Suboptimal valve positioning is a common problem in TAVR [19]. Early devices such as the Sapien transcatheter heart valve, Sapien XT and CoreValve could not be repositioned, making malposition a common cause of dysfunction that often required a second prosthesis. Newer-generation valves have been designed to be repositionable or retrievable, improving deployment accuracy [19]. Paravalvular regurgitation (PVR) results from incomplete sealing between valve and annulus. Once seen in ~12% of first-generation devices, its rate has fallen to ~2% with newer systems [53,54]. Risk factors include annular calcification, asymmetry, undersizing, or malposition, with self-expanding valves particularly implicated [55]. Careful annular sizing reduces this risk [37].

Vascular complications

Access-site injury remains a significant issue, with complications such as hematoma, pseudoaneurysm, dissection, or perforation reported in 10–33% of cases [5,23,56–58]. Risk is influenced by sheath size, vascular anatomy, and patient profile. Alternative approaches (transapical, transaortic, subclavian, axillary, carotid, or retroperitoneal) are recommended for unsuitable iliofemoral anatomy [59–63].

Conduction disorders

Mechanical trauma to the conduction system during implantation can lead to left bundle branch block (LBBB) or complete heart block, often requiring pacemaker implantation. The need for pacing is generally higher after TAVR compared to SAVR [64–67]. Causes include valve design (extension into LVOT), predilatation, valve positioning, or guidewire/catheter trauma [64,68,69].

Stroke

Stroke remains a feared complication due to its mortality and morbidity [52]. Predictors include balloon post-dilatation and valve dislodgement (acute), new-onset atrial fibrillation (subacute), and age, prior AF, stroke, TIA, or vascular disease (late) [70–73]. Incidence has decreased from 4–6% in high-risk cohorts to 0.6–3.4% in recent low-risk trials [74]. Post-procedural antithrombotic therapy—low-dose aspirin alone or dual therapy with aspirin and clopidogrel for 3–6 months—is recommended [29].

Post-procedural Imaging

Post-implantation imaging is divided into immediate and long-term evaluation. Immediately after TAVR, transesophageal echocardiography (TEE) in the hybrid room is the preferred tool to assess valve position, gradients, and effective orifice area [32]. Transthoracic echocardiography (TTE) is also valuable for monitoring early complications and prosthetic valve hemodynamics [29].

Guideline recommendations generally advise TTE at four key intervals: prior to hospital discharge, at 30 days, at 1 year, and annually thereafter [30,75,76]. For long-term surveillance, ECG-gated multidetector CT (MDCT) provides detailed evaluation of prosthesis positioning relative to the annulus, allowing detection of valve malposition or structural issues [77].

Valve-in-Valve TAVR

Valve-in-valve TAVR (ViV TAVR) was first performed in the mid-2000s and later gained FDA approval for high- and extreme-risk patients—Medtronic CoreValve in 2015 and Edwards Sapien in 2017 [78,79]. It is now considered a reasonable alternative to redo SAVR for severe structural valve deterioration, carrying a Class IIa recommendation in the 2017 ACC/AHA guidelines [80]. Despite its advantages, ViV TAVR poses technical challenges, including higher risk of coronary obstruction in certain surgical bioprostheses, elevated residual gradients, and potential valve thrombosis [81]. As randomized evidence remains lacking, long-term registry data are critical to identify which patient subgroups may benefit most from ViV TAVR versus reoperative SAVR, especially among lower-risk populations [81].

TAVR in pure Aortic Regurgitation

TAVR in the setting of native pure aortic regurgitation (AR) presents several anatomical and technical challenges: (i) limited fluoroscopic visualization of the annulus, (ii) lack of

calcification hindering anchoring of the prosthesis, (iii) high stroke volume and turbulent regurgitant flow affecting device stability, (iv) large, elliptical annuli often exceeding the size of available valves, and (v) frequent coexistence of aortopathy with root or ascending aortic dilation [82].

While SAVR remains the standard of care, TAVR can be considered in carefully selected patients with native AR who are deemed high risk for surgery [82]. The latest European guidelines further state that TAVR "may be considered in experienced centres for selected patients with AR who are ineligible for SAVR" [30]. Newer-generation devices with features such as repositionability, self-centering design, and dedicated fixation systems may enhance outcomes in this challenging population [82].

Conclusion

Since its first use in 2002, TAVR has evolved remarkably, becoming an established therapy in many Western countries. However, its high cost limits accessibility in low- and middle-income regions such as Bangladesh. A key contemporary challenge is the shift from treating only symptomatic patients to considering earlier, potentially prophylactic intervention in severe aortic stenosis. Despite ongoing concerns regarding durability, complications, and affordability, TAVR remains one of the most transformative and rapidly advancing areas in interventional cardiology.

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