TAVI for Failing Surgical Aortic Bioprostheses

Based on:

TAVI for Failing Surgical Aortic Bioprostheses

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INTRODUCTION

Among elderly subjects undergoing surgical aortic valve replacement (SAVR), implantation of bioprosthetic heart valves is considered to be the standard of care.[1, 2] These prostheses are recommended for patients ≥60 years of age or in those at high risk of bleeding with systemic anticoagulation.[1, 2] Consequently, the use of bioprosthetic heart valves now greatly outweighs their mechanical equivalents.[3] Despite advances in bioprosthetic design, valve durability remains the Achilles' heel; current iterations are expected to degenerate within 12 to 20 years and in some cases even sooner.[4, 5] Redo SAVR is recommended for stenotic or regurgitant bioprostheses, though surgery is often denied due to elevated operative risk in these elderly patients with comorbid medical conditions.[6-8] In such patients, implantation of a transcatheter aortic valve (TAV) within the degenerated bioprosthetic surgical aortic valve (SAV) has proven to be feasible, safe, and effective.[9-13] Nevertheless, limitations of TAV-in-SAV implantation include a relatively higher rate of malposition and coronary occlusion, device underexpansion, and residual aortic stenosis, compared to native aortic valve TAV implantation (TAVI). This chapter aims to describe the pre-procedural planning, implantation techniques, and evidence for these TAV-in-SAV procedures.

BIOPROSTHETIC SURGICAL AORTIC VALVE CONSTRUCTION

Bioprosthetic SAVs are comprised of two essential components: the valve leaflets and a supporting frame/structure (**Figure 1**).[11] The leaflets may be of xenograft or homograft origin. Xenografts are most frequently composed of bovine pericardium or are whole porcine aortic valves. Less frequently, thinner porcine pericardium may be used for leaflet construction. Typically, the leaflets are prepared with an anti-calcification treatment (e.g. ThermaFix™,

Figure 1. Stented Aortic Bioprosthesis

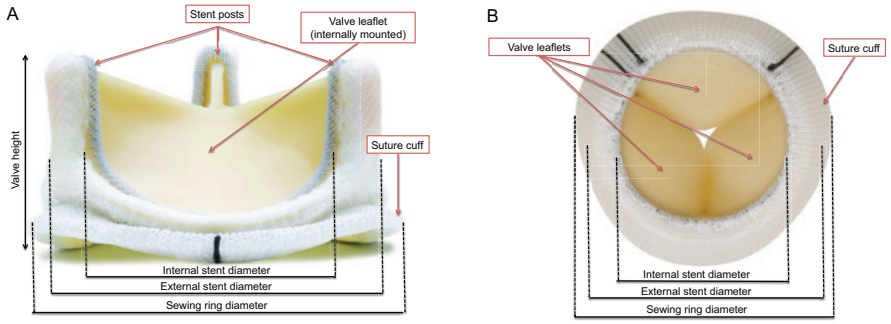


Figure 1. (A and B) Carpentier-Edwards Perimount Magna Ease aortic valve. Dimensions and design features of a stented bioprosthetic valve. With permission from Mylotte et al. EuroIntervention. 2013;9:S77-S83.

Edwards Lifesciences, Irvine, CA, USA) and preserved in glutaraldehyde. Bioprosthetic heart valves can be further categorized according to the leaflet support structure (**Figure 2**): A) stented prostheses where the leaflets are supported by a mechanical frame; or B) stentless prostheses where the leaflets are supported by xeno- or homograft tissue.

Figure 2. Stented and Stentless Bioprosthetic Valves

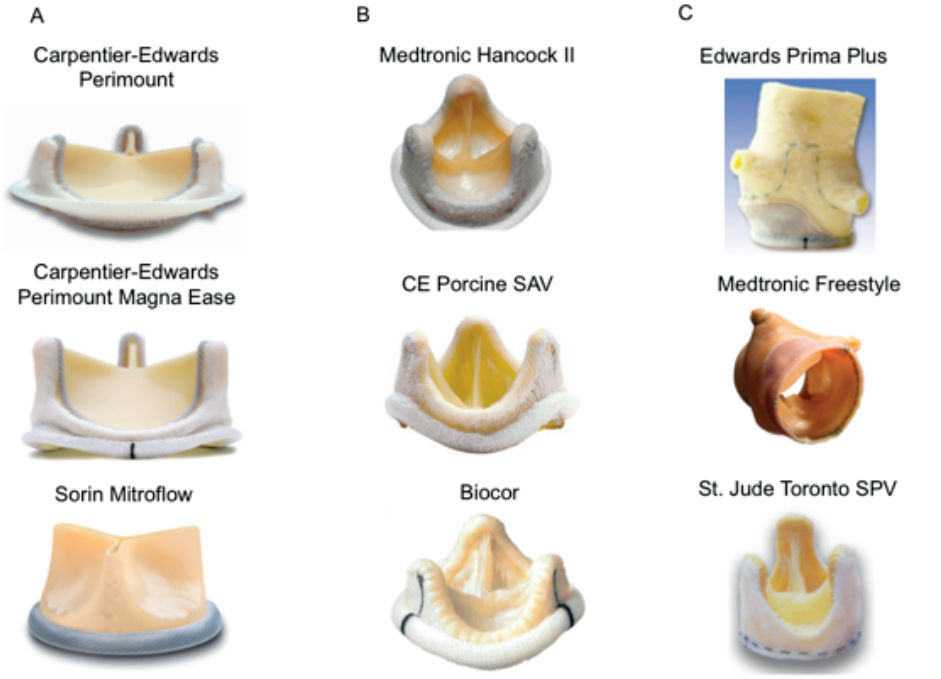


Figure 2. Stented and stentless bioprosthetic surgical valves. (A) Stented pericardial bovine bioprosthetic valves. (B) Stented porcine aortic valve bioprostheses. (C) Stentless bioprosthetic valves. With permission from Mylotte et al. Heart 2013 99: 960-967.

A) Stented Bioprostheses

The basic construction of all stented bioprosthetic heart valves is consistent: valve leaflets sutured to a rigid supporting frame constructed of metallic alloys (titanium or cobalt-chromium), pyrolytic carbon, or polymeric materials (polymers) (**Figure 3**).[14] The stent frame or posts are covered by pericardium or by a synthetic material for protection. A circular or scallop shaped sewing ring is attached to the frame and is usually covered in by a fabric sewing cuff that is used to secure the bioprosthesis to the native aortic root. The valve leaflets may be sited either at the level of the annulus (intra annular Link below)) or above the annulus (supra annular (link to below)) (**Figure 4**). The latter is designed to increase the effective orifice area and improve the haemodynamics of the prosthesis. In most cases, the valve leaflets are sutured

inside the supporting frame, however the Mitroflow (Sorin, British Columbia, Canada) and Trifecta (St. Jude, St Paul, Minnesota, USA) (Link to individual images) bioprostheses have externally mounted leaflets wrapped as a sleeve around the frame.

Figure 3. Stented Bioprosthetic Valve Construction

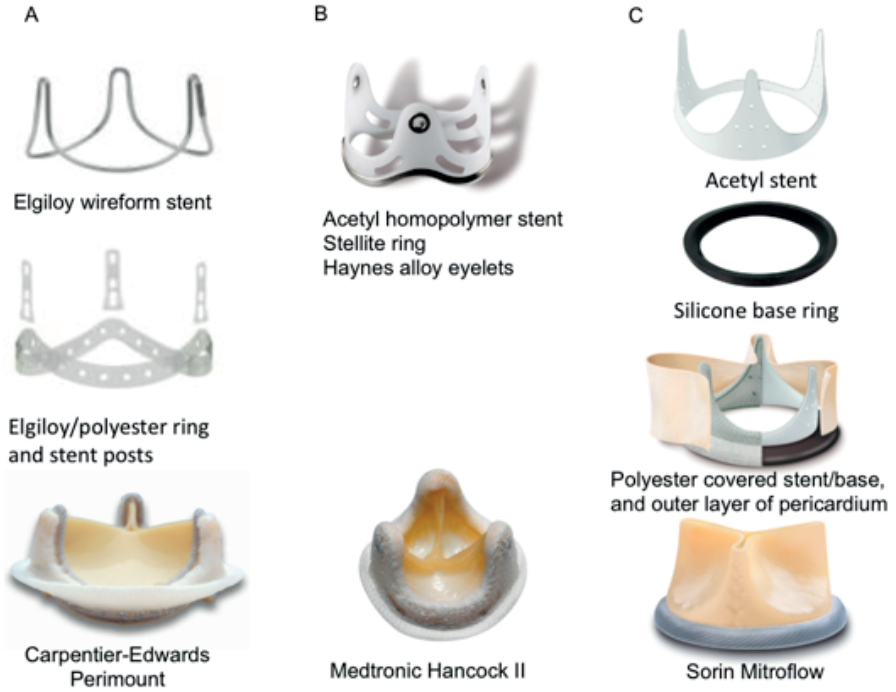


Figure 3. (A) Carpentier-Edwards Perimount bovine pericardial valve. (B) Medtronic Hancock II porcine aortic valve. (C) Sorin Mitroflow bovine pericardial valve. With permission from Mylotte et al. Heart 2013 99: 960-967.

Figure 4. Intra and Supra Annular Bioprostheses

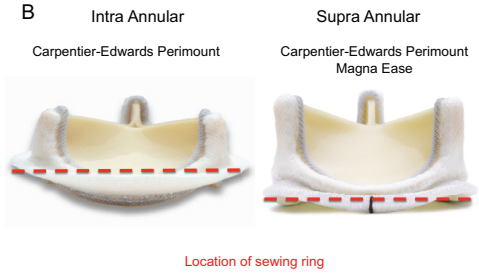


Figure 4. (A) Intra (Carpentier Edwards Perimount) and supra (Carpentier Edwards Perimount Magna Ease) annular bioprostheses. Note (B) the location of the sewing ring is different.

Fluoroscopic Identification of Stented Bioprosthesis

The stent frame or posts and the sewing ring may be radiolucent or radiopaque, according to their composition. Fluoroscopic identification of stented surgical bioprostheses is performed by discerning differences in the shape of the frame and/or the design and location of the sewing ring.[11] The Aortic Valve-in-Valve (VIV) application includes a user-friendly, comprehensive, guide that assists in the identification of aortic bioprosthetic valves.

B) Stentless Bioprostheses

Stentless bioprostheses do not have a supporting frame and/or ring. Rather, these valves are entirely constructed from human (homograft) or porcine (xenograft) aortic root tissue.[15] Examples include: Edwards Prima; Medtronic Freestyle, Sorin Freedom; St Jude Toronto SPV. These prostheses were principally developed to yield superior haemodynamic results to their stented equivalents. Stentless bioprostheses have not been proven to enhance durability when compared to their stented equivalents.[16] Furthermore, their propensity towards heavy aortic root calcification and lack of fluoroscopic markers can make TAV-in-SAV more challenging.[17]

FAILURE MODES OF SURGICAL BIOPROSTHESES

The increasing use of surgical bioprosthetic valves has resulted in physicians encountering bioprosthesis failure with greater frequency. First generation bioprosthetic heart valves were particularly prone to failure: up to one-third of younger patients underwent reoperation within 10 years.[18] Technical advances have rendered these early prostheses obsolete, and have improved valve durability: freedom from structural valve failure at 15-years was reported in 43% of those treated with the first generation Hancock bioprosthesis (Medtronic, Minneapolis, Minnesota, USA) and in 19% treated with the second-generation Hancock valve.[19, 20] Current, third-generation bioprostheses are expected to further reduce the incidence of structural valve failure, though long-term durability data are not yet available. Overall, the median life-span of surgical bioprostheses is currently between 12 to 20 years with current prostheses,[4, 5] however there appears to be a cohort of patients that experience early valve failure: the median time to failure in the Global VIV registry was 9 years.[12] It is also conceivable that because many bioprosthetic recipients are elderly and high-risk for redo surgery, that the true incidence of aortic bioprosthesis failure may be under-reported. Smoking, younger age, persistent left ventricular hypertrophy and small prosthesis sizes are predictors of requirement for reoperation.[4, 6] In addition, metabolic syndrome, diabetes mellitus, renal insufficiency, and higher mean valve gradient at baseline significantly contribute to structural valve deterioration over time of bioprostheses.[21]

Valve leaflet deterioration, due to wear and tear, progressive calcification, infective endocarditis, thrombosis or extensive pannus formation is the most common mechanism of

bioprosthetic failure (**Figure 5**).[11, 22] Structural fatigue of the valve frame or stent posts, and paravalvular regurgitation in the presence of a functionally normal prosthesis may also necessitate redo surgery. Isolated bioprosthetic stenosis is observed more frequently than isolated regurgitation in stented bioprostheses whereas stentless bioprostheses commonly fail with predominant regurgitation or mixed valve failure.[12] In the preliminary report of the Global VIV registry (n=202), bioprosthesis mode of failure was stenosis (42%), regurgitation (34%), or combined stenosis and regurgitation (24%).

Figure 5. Aetiology of Surgical Bioprosthesis Failure

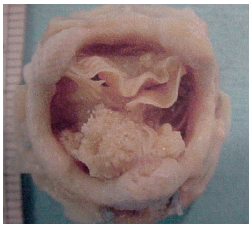


Figure 5. Pathological specimens demonstrating the aetiology of bioprosthetic valve failure. (A) Wear and tear. (B) Calcific degeneration. (C) Pannus. (D) Endocarditis. (E) Thrombus. With permission from Piazza N et al. JACC Intv 2011;4:721–32.

SIZE LABELLING OF SURGICAL BIOPROSTHESES: IMPLICATIONS FOR TAV-IN-SAV

Understanding the sizing nomenclature of surgical bioprostheses is of utmost importance for planning and executing properly the TAV-in-SAV procedures (**Figure 1**). The internal stent diameter represents the internal diameter of the frame of stented surgical bioprostheses, without the valve leaflets. This measurement, among other scaffold dimensions (external stent diameter; sewing ring diameter), is commonly available from the prosthesis manufacturer. However, when the valve leaflets are considered, the dimensions of the bioprosthesis with internally mounted leaflets are smaller than the labelled inner stent diameter. This, "true" internal diameter is typically 2.0 mm smaller for valves with internally mounted porcine leaflets (Hancock II), Mosaic, CE Porcine SAV, Epic and Biocor) and 1.0 mm smaller in valves composed of pericardial tissue (Perimount, Perimount 2700, Magna, Magna Ease, Soprano).[23] With externally mounted leaflets, the internal stent diameter is equal to the "true" internal diameter.[23] The presence of heavy leaflet calcification and/or pannus can further reduce the diameter available for TAV implantation.

The manufacturer-labelled diameter of stentless valves typically corresponds to the external (aortic root diameter) of the valve. Although the labelled diameter can be somewhat variable, due to the ability to distend these pliable valves, the "true" internal diameter is approximately 1.5 mm (Prima), 3 mm (Freestyle), or 2 mm (Toronto SPV) smaller than the labelled size.[23]

TAV SIZING

In TAVI for native aortic valve stenosis, oversizing the transcatheter heart valve (THV) relative to the aortic annulus is required (1) to anchor the prosthesis and prevent valve migration; (2) to provide sealing and avoid paravalvular leaks; and (3) to minimise patient-prosthesis mismatch. The degree of THV oversizing is prosthesis specific (Edwards SAPIEN: 4 to 20%; CoreValve 7 to 30%) and is greatly influenced by the imaging modality (echocardiographic vs. computed tomography [CT]) and by the method of diameter calculation (area; mean diameter; perimeter).

Currently, the amount of THV oversizing and the optimal method of THV-sizing for TAV-in-SAV procedures remain unknown. The required degree of THV oversizing relative to the degenerated bioprosthesis may be less than that advised for native aortic stenosis, as prosthesis anchoring and sealing appear to be superior within the frame of the surgical valve and the rate of significant post-procedural paravalvular aortic regurgitation appears low. Although the risk of excessive oversizing with regard to annular rupture is low in these cases, aggressive oversizing may hypothetically risk high post-implantation transvalvular gradients and may threaten longer-term valve durability. There is consensus, that CT evaluation of the "true diameter" of the degenerated bioprosthesis may be the most appropriate method of sizing.[17, 24] CT affords assessment of the impact of the valve leaflets, calcification, and pannus formation on the manufacturer-labelled internal diameter. The authors strongly recommend the sizing algorithm proposed in the Aortic VIV application.

EVIDENCE FOR TAV-IN-SAV PROCEDURES

Evidence supporting the safety and efficacy of TAV-in-SAV procedures was initially derived from case reports and small series.[10, 13, 25-30] In 2010, the Global VIV registry began collecting data from centres performing TAV-in-SAV procedures across the globe.[12] Most recently, this voluntary registry reported outcomes on 459 patients (n=213: CoreValve; n=246 Edwards SAPIEN) with a failed surgical aortic bioprosthesis treated by TAV-in-SAV.[31]

The complexity of these procedures was demonstrated by satisfactory procedural success and clinical results but also by high rates of TAVI malposition: stented prostheses (8%); stentless prostheses (14%); and by the requirement for a second transcatheter valve in 4.5%. Coronary artery obstruction occurred in 2% and conversion to surgical aortic valve replacement was required in 3.4%. Overall 30-day mortality was 7.6%, (7.0% CoreValve and 8.1% Edwards SAPIEN). At 1-year, 85% of CoreValve and 81.3% of Edwards SAPIEN treated patients were alive (p=0.44). The strongest independent predictors for post-procedural mortality were a small surgical valve size (label size <=21mm) and stenosis as the failure mechanism.[31]

PROCEDURAL COMPLICATIONS

Post Implantation Gradients

In the setting of THV implantation for native aortic valve stenosis, mean transvalvular gradients average 5 to 15 mmHg. In contrast, mean transvalvular gradients following TAV-in-SAV are frequently higher: 10 – 25 mmHg. In the Global VIV registry, 28.4% of cases had elevated post-procedural gradients.[12] Consequently, a large proportion of TAV-in-SAV cases do not meet the Valve Academic Research Consortium (VARC) definition for acute procedural success [32]. The restricted area for THV expansion within the degenerated surgical bioprosthesis or pre-existing patient-prosthesis mismatch is the most likely explanations for these elevated gradients. Indeed, the smaller the surgical bioprosthesis, the higher the gradient that can be expected following THV implantation.[33] Importantly, the Medtronic CoreValve seems to deliver superior haemodynamic performance than the Edwards SAPIEN in surgical bioprostheses of small (< 20 mm) or intermediate (>20 < 23 mm) internal diameter.[31] This discrepancy arises from the different design characteristics of these devices: the functional component of the Edwards SAPIEN system is located at the level of the native annulus while the CoreValve's leaflets are supra-annular (**Figure 6**). Thus, the CoreValve is ultimately less constrained by the rigid frame of the surgical bioprosthesis into which it is implanted and provides a larger effective orifice area. Whether this haemodynamic superiority translates into enhanced long-term clinical outcomes is not yet know. Going forward, it is expected that

Figure 6. Bench Morphology of TAV-in-SAV

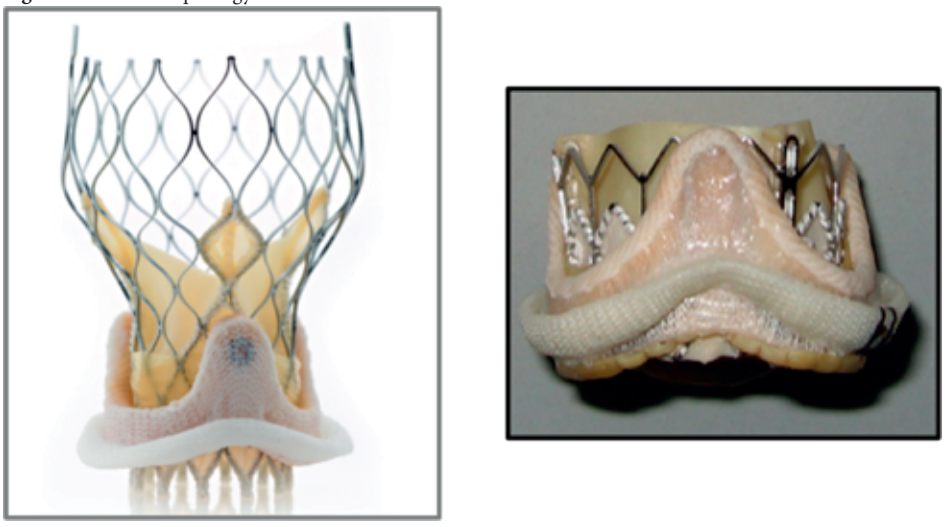


Figure 6. Bench morphology of the Medtronic CoreValve (left) and Edwards SAPIEN valve (right) within stented surgical bioprosthetic valves.

the newly developed 23mm CoreValve and 20mm Edwards SAPIEN prostheses will impact positively on post-implantation gradients.[34, 35]

TAV-in-SAV procedures have been performed using a range of prostheses: Medtronic CoreValve,[10] Medtronic CoreValve Evolut R,[34] Medtronic Melody,[36] Edwards SAPIEN,[37] St Jude Portico,[38] and Symetis Acurate.[39] Most procedures however, have been performed with either the Edwards SAPIEN or Medtronic CoreValve systems.[12]

THV Malposition

THV malposition was reported in 15.3% of cases in the Global VIV registry.[12] Consequently, high rates of additional manoeuvres to reposition or retrieve the valve or implantation of a second THV (8% of total cohort) were observed.[12] More recently, the requirement for implantation of a second THV appear to have fallen to 4.3%.[31] Operator experience is likely to have had an important role in these improving results:[24] improved understanding of bioprosthesis construction and mode of failure; understanding the ideal implant position for a given bioprosthesis (e.g. different for annular and supra annular bioprostheses); and utilization of intra-procedural multimodality imaging. Stentless bioprostheses and stented valves with radiolucent sewing rings (Epic, St. Jude; Mosaic, Medtronic) provide the greatest challenge to accurate THV positioning.

Paravalvular Leak

Significant paravalvular regurgitation between the THV and the surgical bioprosthesis are uncommon (5%).[12] The frame of the surgical valve appears to improve THV sealing and thus the majority of cases of significant paravalvular regurgitation arise from THV malposition.[24] In the absence of malposition, incomplete THV expansion may be treated with post implantation balloon dilatation.

Coronary Obstruction

There is an elevated risk of coronary obstruction with TAV-in-SAV procedures compared to TAVI for native aortic stenosis.[24, 40] Coronary obstruction was observed in 3.5% of cases in the initial publication of the Global VIV registry. Most recently, the rate of coronary obstruction in the expanded registry was reported to be 2%.[31] Left coronary artery obstruction occurs more commonly and is usually associated with haemodynamic instability and ventricular arrhythmia.[40] The most common mechanism for coronary obstruction is thought to be displacement of the leaflets of the bioprosthesis towards the ostium of the coronary artery or towards the sinutubular junction. A reduced distance between the bioprosthetic leaflets and/or stent posts and the coronary ostia may increase the risk of coronary occlusion. Several factors may increase this risk: low-lying coronary arteries and/or sinutubular junction; narrow aortic sinuses of Valsalva; supra annular bioprosthesis; elongated leaflets; bulky pannus or calcification.[24] The design of the surgical bioprosthesis may increase the risk of coronary obstruction.

Stentless bioprostheses (Freedom, (Sorin, British Columbia, Canada) and Trifecta (St Jude, St. Paul, Minneapolis, USA) add links) or those with externally mounted leaflets (Mitroflow, Sorin) increase the risk of coronary obstruction as the leaflets may extend outward in a tubular fashion following TAV-in-SAV.

Stroke

Degenerated surgical bioprosthetic valve leaflets may be heavily calcified and/or friable, and prone to tearing, and therefore may have embolic potential. It was assumed therefore, that TAV-in-SAV procedures might carry a higher risk of stroke than TAVI for native aortic stenosis. The Global VIV registry reported major stroke rates of 0.9% for CoreValve and 2.4% for Edwards SAPIEN recipients. These rates are comparable to published series for TAVI in native aortic stenosis.[41] Nonetheless, lack of pre-implantation valvuloplasty during TAV-in-SAV in most cases may have contributed to the low risk of stroke among failed bioprosthetic valve patients.

TAV-IN-SAV: PROCEDURAL TIPS AND TRICKS

Patient Selection

The patient work-up for a TAV-in-SAV procedure should be extensive and thorough. Details of the initial surgical procedure should be sought and the indication for surgery, type and size of the surgical prosthesis documented. The bioprosthetic stenosis or regurgitation, or both, requires confirmation with echocardiography. However, it must be demonstrated that the bioprosthesis is indeed failing and stenotic, rather than there being a chronically elevated gradient due to a small surgical valve. Similarly, in cases of significant bioprosthesis incompetence, it is important to demonstrate that the aortic regurgitation is transvalvular rather than paravalvular. Ruling out active bioprosthetic infective endocarditis or valve thrombosis as failure mechanisms can also be achieved with echocardiography and laboratory testing. We advocate that all patients under consideration for TAV-in-SAV undergo CT analysis for the purposes of THV-sizing and access route selection and transoesophageal echocardiography in cases with predominant regurgitation in order to exclude paravalvular leak.

THV Selection

The choice of THV for implantation should be individualized for each patient. In the majority of cases, the Edwards SAPIEN (**Figure 7**) or CoreValve (**Figure 8**) are likely to be equally efficacious. Patients with bioprostheses of small (<20 mm) internal diameter may benefit from the superior haemodynamic results associated with the CoreValve.[31] Consideration of the risk of coronary ostial occlusion may also influence THV selection. New generation, fully retrievable THV devices or those with aortic leaflet clipping (Jena valve) may be preferable if the risk

Figure 7. Edwards SAPIEN TAV-in-SAV

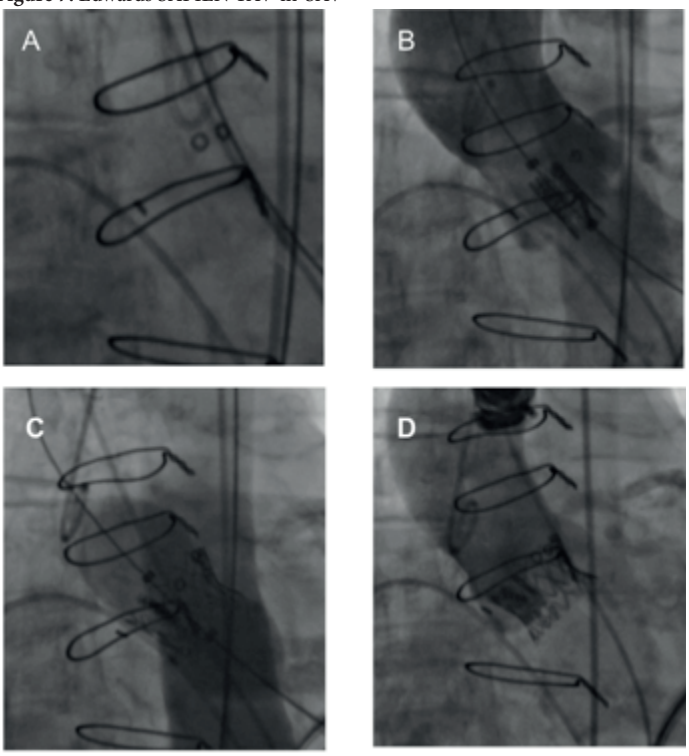


Figure 7. Edwards SAPIEN TAV-in-SAV procedure. Transapical implantation of a 23 mm Edwards SAPIEN TAV inside a 21 mm Medtronic Mosaic bioprosthesis. (A) Fluoroscopic identification of the Medtronic Mosaic valve. (B) Positioning of the Edwards SAPIEN valve. (C) Deployment of the Edwards SAPIEN valve. (D) Final contrast aortography. With permission from Mylotte et al. Heart 2013 99: 960-967.

Figure 8. Medtronic CoreValve TAV-in-SAV

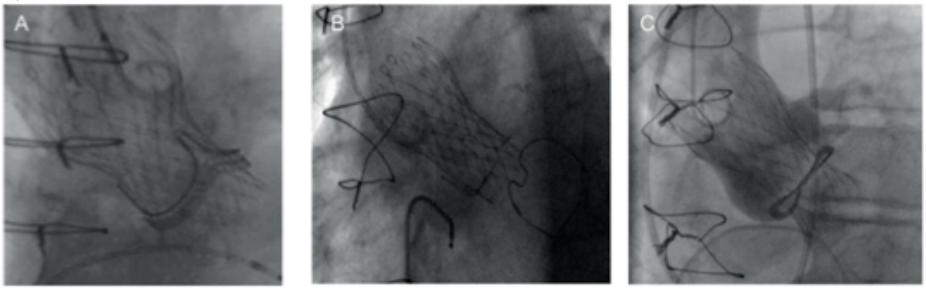


Figure 8. Medtronic CoreValve transcatheter aortic valve in surgical aortic valve (TAV-in-SAV) procedures. Medtronic CoreValve prosthesis implantation within (A) Edwards Perimount, (B) Carpentier-Edwards Porcine Supra-Annular Valve, and (C) Sorin Soprano bioprosthesis. With permission from Mylotte et al. Heart 2013 99: 960-967.

of coronary occlusion is deemed to be high. Furthermore, if the risk of coronary occlusion seems high, a safety wire (with/without a loaded stent) can be placed in the coronary arteries to facilitate and/or expedite percutaneous coronary intervention (**Figure 9**).

Figure 9. TAV-in-SAV with Prophylactic Left Main Coronary Protection.

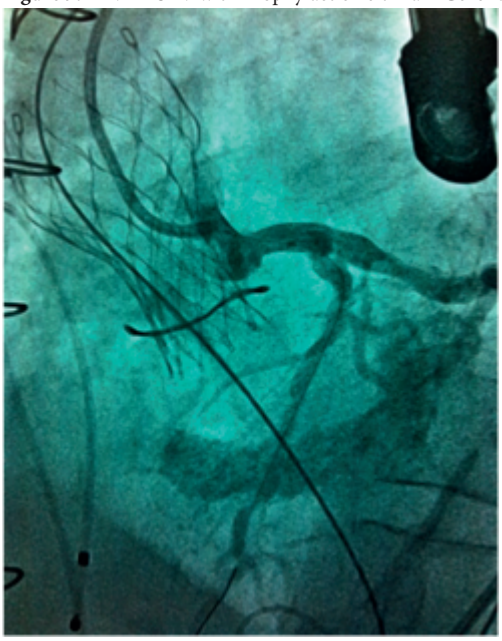


Figure 9. Implantation of a Medtronic CoreValve within a 19 mm Sorin Mitroflow bioprosthesis, facilitated by placing a 0.014 guide wire into the distal left circumflex. Note the pre-mounted balloon in the left main stem.

Balloon Predilatation

Current guidelines discourage balloon valvuloplasty of degenerative bioprostheses on the left side of the heart as a single procedure because of a significant risk of hemodynamic compromise following inadvertent leaflet tear.[2, 42] Certainly, there is little to be gained from pre-emptive balloon valvuloplasty in the setting of primary bioprosthesis regurgitation or in transapical cases with antegrade crossing of the aortic valve. In contrast, if difficulty crossing a stenotic bioprosthesis or if suboptimal THV expansion is envisaged due to severe calcification or pannus formation, then upfront valvuloplasty with an undersized balloon may be appropriate.

THV Positioning

As with TAVI for native aortic stenosis, the optimal fluoroscopic angle for implantation should be chosen. This is achieved by lining up the fluoroscopic markers, particularly the sewing ring along a single plane. Understanding the construction of the surgical bioprosthesis is axiomatic.[10] The recently developed Aortic VIV Application (Link) provides a very useful

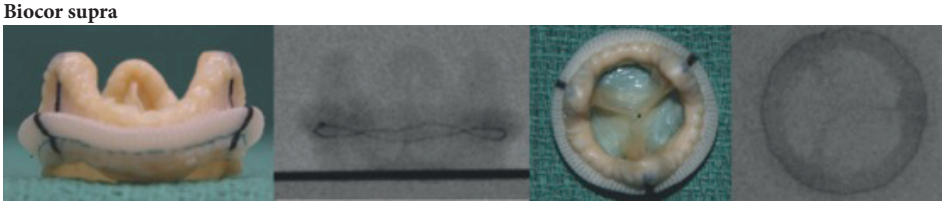
guide for THV positioning in available bioprostheses. In stented bioprostheses, the sewing ring is the most rigid structure and provides the anchor for THV implantation. For supra annular bioprostheses, the Edwards SAPIEN and the CoreValve should be positioned 15-20% and 4 mm below the lowest fluoroscopic part of the stent, respectively. For intra annular bioprostheses, the Edwards SAPIEN and the CoreValve should be positioned 15-20% and 4 mm below the sewing ring, respectively. Intraprocedural transoesophageal echocardiography is strongly recommended to aid in positioning in cases with stentless valves or for stented valves with radiolucent sewing rings or when the leaflets are noncalcified or regurgitant. Stable guide wire position and coaxial implantation of the THV are essential for accurate positioning. Ventricular pacing should be considered for patients with greater than mild bioprosthetic regurgitation. The Edwards SAPIEN valve is probably best inflated gradually and slowly, as small adjustments can be made during deployment to optimise positioning. Cautious initial deployment of the CoreValve is essential as further positioning of the THV is extremely difficult or even impossible once firm contact has been made with the frame of the surgical valve. Ventricular pacing or breath-hold may also facilitate deployment. Second-generation TAVI systems that are recapturable and repositionable will hopefully reduce the incidence of THV malposition.[34]

Durability of TAV-in-SAV

Since TAV-in-SAV is a relatively new procedure, the long-term durability of such approach has to be defined. Anecdotal cases of earlier than expected valve deteriorations have been presented at professional meetings, yet rarely reported in the medical literature.[43] The long-term quality and functionality of the implanted catheter-based valve in the setting of TAV-in-SAV will dictate how widely this therapeutic strategy can be offered to patients with surgical bioprosthetic valve deterioration.

Figure 10. Bioprosthetic Heart Valves Gallery

Biocor supra



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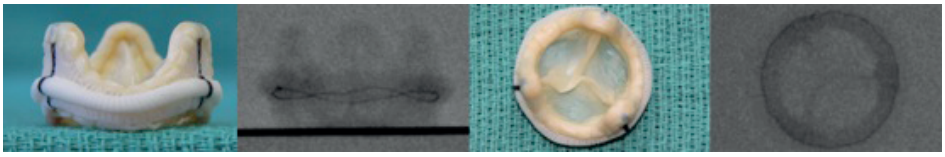
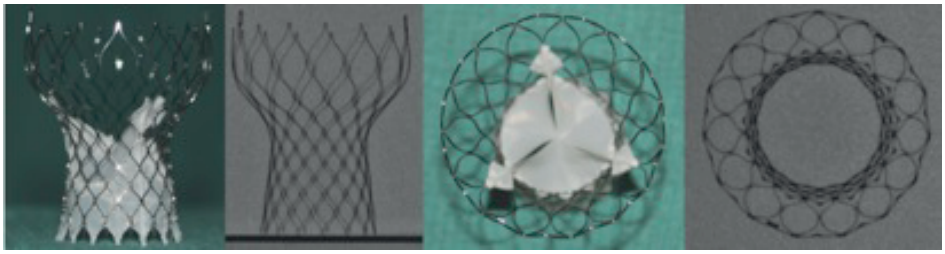
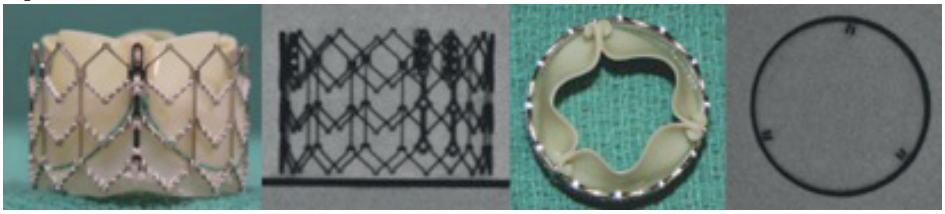


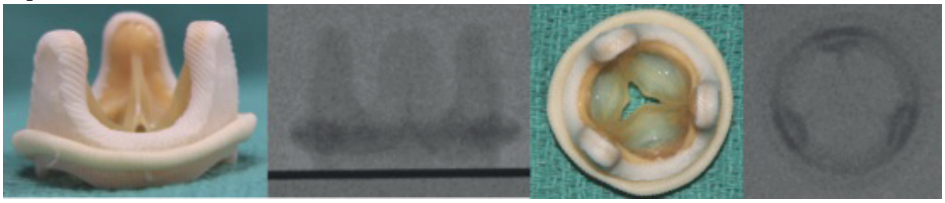
CoreValve



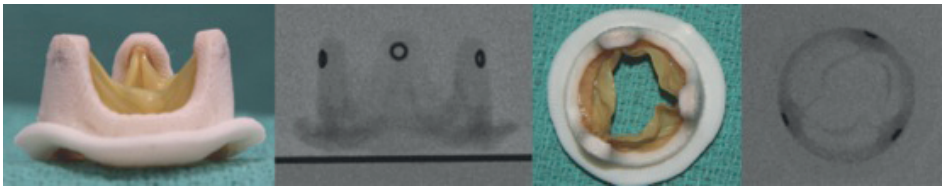
Sapien



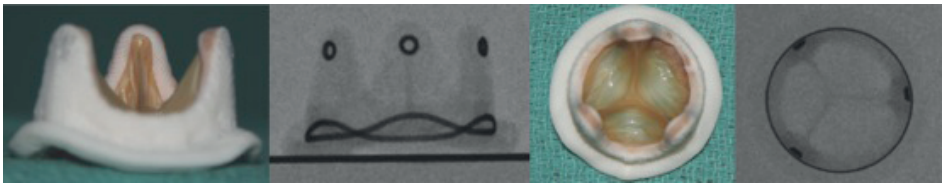
Aspire



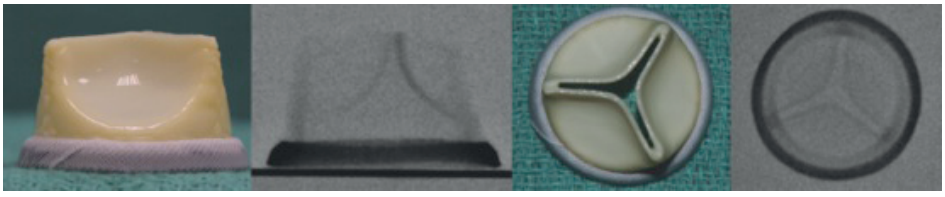
Mosaic



Hancock



Mitroflow



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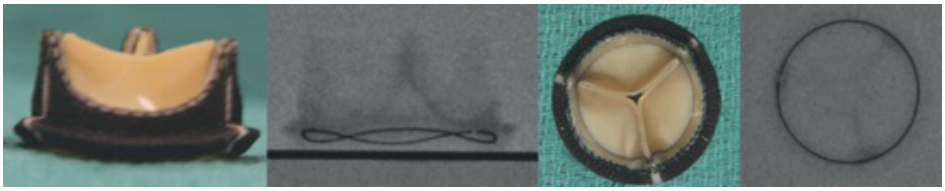

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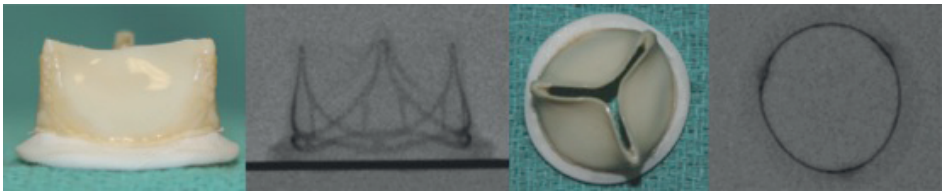

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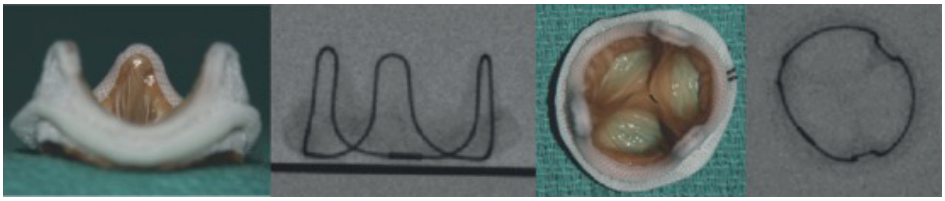

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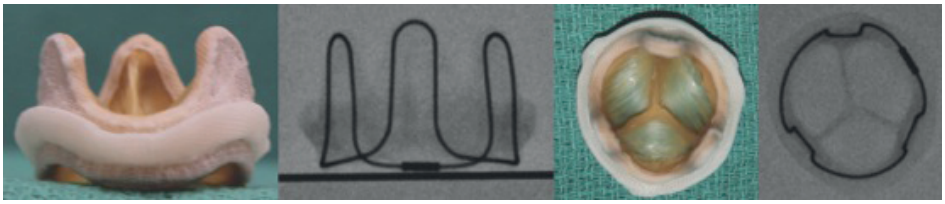

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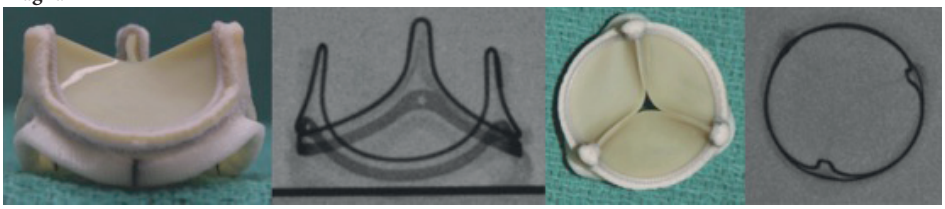

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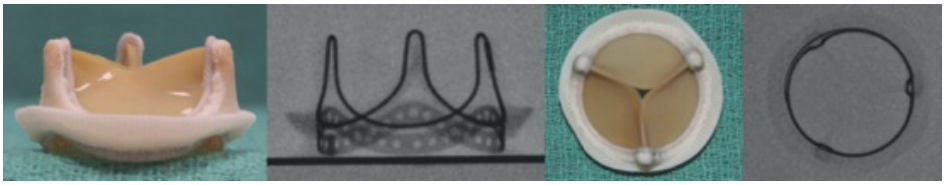

Figure 10. Surgical bioprosthetic valves visualized from the side and the corresponding fluoroscopic image, and from above, with corresponding fluoroscopic image (left to right)

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