

Transcatheter aortic valve replacement valve-in-valve: Future implications for the surgeon



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A 50-year-old engineer comes to your office with a recent diagnosis of severe, symptomatic aortic stenosis. He evaluated his options and has decided he wants a bioprosthetic valve. He is sure whenever the valve degenerates he will be able to get a transcatheter aortic valve replacement (TAVR) and not have to undergo reoperative heart surgery. Is there anything that should be done at the time of his surgical bioprosthetic aortic valve replacement to give him the best chance of being a valve-in-valve (ViV) TAVR candidate?

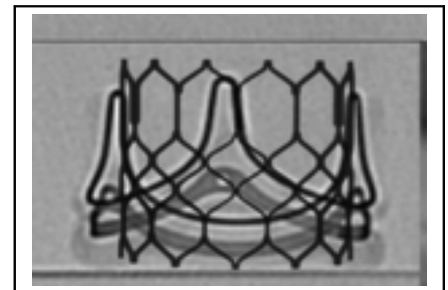
Thoughtful planning regarding prosthesis choice, valve size, anatomic orientation, root anatomy, and the radiographic signature of the valve annulus can greatly improve the chances of successful transcatheter ViV replacement for severe structural valve degeneration.¹⁻³

IDEAL PROSTHESIS

The ideal bioprosthetic surgical prosthesis has a large effective orifice area (EOA), its sewing ring and stent frame can expand in vivo at low pressures, it has a unique, easily-seen radiographic profile, and the leaflets are implanted on short stents that won't obstruct native coronary arteries upon deployment of a TAVR. The ideal anatomical features of a patient's aortic root that would make ViV TAVR most likely to be feasible are a large surgical valve, coronary arteries that originate high above the level of the annulus, and well-developed, tall aortic sinuses. Understanding these factors and careful surgical planning can optimize the chance of future success.

VALVE SIZING

Patient-prosthesis mismatch (PPM), defined as valve EOA indexed to body surface area (BSA) of less than $0.85 \text{ cm}^2/\text{m}^2$, must be avoided and can never be overcome with a subsequent transcatheter procedure. Using the patient's height and weight, the minimum EOA of the implanted valve needed to avoid PPM can be identified. The EOA of each surgical valve is unique and based on factors



Fluoroscopic image of a transcatheter valve inside a surgical valve.

CENTRAL MESSAGE

Prosthesis sizing, radiographic marking of the annular plane, and evaluating risk of coronary obstruction upon TAVR deployment are key to valve-in-valve success.

such as the material used to construct the leaflets, whether the leaflets are mounted on the inside or outside of the stent, and the size of the valve stent. Thus, all "21 mm"-sized aortic valves do not have the same EOA.⁴ Using readily available charts or online applications,⁵ the EOA for each size of the valve being implanted can be identified. Based on the patient's BSA, you can determine the minimum size valve needed to implant to avoid PPM.

A preoperative computed tomography scan can help you anticipate what size surgical valve will easily fit. Using an aortic valve protocol, you can get a good sense of the annular dimensions and the size of the sinotubular junction. If the minimum valve size you need to implant will easily fit, you can true size the annulus and place whichever valve is appropriate. If the dimensions suggest that the minimum-sized valve needed to avoid PPM will not fit, you should be prepared to do a root enlargement.

Multiple techniques for enlarging the aortic root have been described and it can be done with minimal impact on morbidity or mortality.⁶⁻⁹ The aortotomy used to access the valve is taken down the noncoronary sinus and through the annulus at either the nadir of the noncoronary cusp (Nicks) or the commissure between the left and

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noncoronary cusps (Manouagian). Yang⁹ has described his technique of root enlargement, which involves incising the annulus through the left-noncommissure and making a “Y-incision” on either side in the aorto-mitral curtain. A patch is then sewn to the annulus and subannular tissue on both sides of the incision to create a wider annulus. The annular valve sutures in the enlarged area are taken through the patch and the valve in that area sits on the patch. These techniques typically allow a valve 1-to-2 sizes bigger to be implanted.

As many surgical aortic valve replacements are now done through less-invasive techniques, knowing preoperatively whether you will need to do a root enlargement can help you plan as it may change your approach or allow for a more efficient operation.

RADIOGRAPHIC SIGNATURE

The ideal deployment of a ViV TAVR yields a secure implant with optimal hemodynamics and unobstructed coronary arteries. Malpositioned deployment, high transvalvular gradient, and coronary obstruction tend to be the biggest factors that doom ViV therapy. Keeping these in mind at the time of surgery can increase the success rate for ViV.

Most surgical valves have 3 components: the leaflets, the stent, and a sewing ring. The sewing ring is the narrowest and most secure plane for the TAVR deployment. The ideal deployment position is realized when the bottom of the transcatheter frame is deployed 5 mm below the level of the sewing ring. As such, it is critical that the sewing ring is well-visualized fluoroscopically.

Surgical valves can either be intra-annular or supra-annular. Intra-annular valves have the stents below the level of the sewing ring. Supra-annular valves have the stents at the level of the sewing ring. Each surgical valve has a unique fluoroscopic signature which may correspond to either the sewing ring, stent, or both. If the valve is intra-annular, the stent frame will be below the sewing ring but may be what is seen fluoroscopically. As such, it is critical to know which valve was used and whether the level of the sewing ring or stent frame is seen fluoroscopically to ensure proper deployment height.

Not all valves or valve conduits have a radiopaque signature. Biologic root replacements such as pulmonary autograft, homograft, and xenograft roots do not have any metallic component. Some newer surgical valves are stentless and as such aren't seen radiographically. In these cases, marking the annular plane with clips or a radiopaque marker will make a future ViV much safer.

SEWING RING EXPANSION

Complete valve expansion is critical to achieve optimal valve function and avoid a high postoperative residual gradient or paravalvular leak. Incomplete and uneven expansion are both problematic. Conversely, the

transcatheter valve needs to be large enough relative to the sewing ring size that it is properly secured. As such, choosing the right transcatheter valve size is critical.

If the surgical valve implanted was on the smaller size, either absolutely or relative to the patient's BSA, doing a ViV with a small TAVR valve may leave a high residual gradient. One way to help overcome this is to “crack” or fracture the sewing ring to allow for additional expansion. Some, not all, surgical valves can be cracked. Some require a high-pressure balloon, placing additional risk to the patient. Taking into consideration the possibility of ViV down the road, implanting a valve with an easily expandable sewing ring and stent frame may be very useful, especially when implanting smaller valves. In addition, stentless valve frames are made of a material that allows for easy expansion.

RELATIONSHIP TO CORONARY ARTERIES

Coronary obstruction is a lethal complication of ViV TAVR. The most common mechanism is the surgical valve leaflets being pushed aside at deployment and obstructing the lumen of a coronary artery. This is of more significant concern in patients with a deficient left or right sinus segment or a short, narrow sinotubular junction in relation to the prosthesis leading to sinus sequestration.¹⁰

The coronary arteries are typically near the middle of the respective sinus segments in patients with trileaflet aortic valves. In patients with bicuspid valves, who incidentally are often the younger patients requesting tissue valves that are likely to degenerate during their lifetime, the coronary anatomy is often distorted. This may mean that a coronary artery is oriented more closely to a commissure or directly across from the other coronary. Paying close attention to post orientation in relation to the coronary ostia can help avoid obstruction at the time of surgery but also during future ViV.

If the arteries are known to be low, prosthesis selection can be helpful to keep options open. Using a valve where the leaflets are inside the sewing ring will leave a couple of millimeters between the leaflet edge and the arterial wall for coronary flow. Use of a low-profile valve also may be useful in a patient who has a low riding coronary artery.

An option in patient with deficient sinus segments or those at high risk for sequestration is a root enlargement that focuses on widening the sinotubular junction. Another option when considering adjunctive procedures to the root is an aortic root replacement. Consideration of this may be appropriate in patients requiring annular augmentation with narrow sinuses or a low sinotubular junction. A valve-conduit with prefabricated sinus segments can be used which may set up better for future transcatheter ViV therapies.

SURGERY

When evaluating treatment options for a patient with severe structural valve deterioration, the risk of reoperative surgical aortic valve replacement should always be assessed. Although factors such as duration of hospitalization and recovery time are undoubtedly longer following surgery, reoperation status alone has been shown to not significantly factor in the overall risk of surgery.¹¹ In some cases, reoperative surgical aortic valve replacement will remain the patient's safest or most effective option.

Circling back to the patient described at the beginning of this article, he subsequently undergoes successful surgical aortic valve replacement. Over the next 10 to 20 years, he develops severe structural valve deterioration. Based on our current understanding of transcatheter ViV therapies, what is the best treatment for an otherwise-healthy 70-year-old with severe, symptomatic aortic stenosis secondary to structural valve degeneration who is anatomically a good candidate for ViV TAVR?

Long-term outcome data regarding ViV TAVR remain quite limited. Deharo and colleagues¹² compared patients undergoing ViV TAVR with those undergoing redo-aortic valve replacement and those who underwent TAVR had significantly less perioperative risk. However, a composite outcome including death, stroke, myocardial infarction, and rehospitalization caught up to surgery at around 2 to 3 years with limited follow-up beyond that. Pacemaker implantation rate was greater in the ViV group.

The prosthesis durability of ViV TAVR compared with surgical aortic valves remains unknown. Webb and colleagues¹³ published results of ViV TAVR in high-risk reoperative patients from the PARTNER 2 (Placement of Aortic Transcatheter Valves 2) Registry and found acceptable early hemodynamics with a mean gradient of 16 mm Hg and no significant degradation of valve function at 3 years. Others have found primary TAVR valve durability in elderly populations similar to that of surgical valves at 5 years.^{14,15} Whether these trends continue, are replicated in low-risk patients, and are replicated in the ViV setting is not known.

If a patient does undergo ViV TAVR and needs a redo surgical aortic valve replacement later, we have some recent insight in what that risk entails. In a multicenter registry encompassing 269 patients in 42 centers, the EXPLANT-TAVR investigators found patients undergoing TAVR explant had an 11.9% in-hospital mortality and 13.1% 30-day mortality, more than double the average Society of Thoracic Surgeons Risk Prediction for the group (5.6%). In addition, those patients had a 5.9% and 8.6% in-hospital and 30-day stroke risk, respectively.¹⁶ This study doesn't necessarily represent all TAVR explant risk, as more than 50% of these were urgent or emergent and only 20% were done for structural valve degeneration. It

is certainly an indication the risk of TAVR explant aortic valve replacement is not equal to isolated aortic valve replacement.

Elderly patients and those at high-risk for reoperative surgical aortic valve replacement are great candidates for ViV TAVR. Whether younger patients with few comorbidities and the ability to recover from surgery are best served by transcatheter valve replacement or should undergo reoperative surgical aortic valve replacement is unknown.

CONCLUSIONS

Transcatheter aortic valve replacement has an excellent safety profile, effectively treats aortic valve disease, and prevents patients from having to undergo redo sternotomy for structural valve degeneration. Decisions made at the time of surgical aortic valve replacement including valve sizing, orientation, fluoroscopic marking, and use of adjunctive procedures when indicated help patients' candidacy to receive a TAVR in the future.

Conflict of Interest Statement

Dr Bapat serves as a consultant for Edwards, Boston Scientific, Medtronic, and Abbott. Dr Steffen reported no conflicts of interest.

The *Journal* policy requires editors and reviewers to disclose conflicts of interest and to decline handling or reviewing manuscripts for which they may have a conflict of interest. The editors and reviewers of this article have no conflicts of interest.

References

1. Bapat VN, Attia R, Thomas M. Effect of valve design on the stent internal diameter of a bioprosthetic valve. *JACC Cardiovasc Interv.* 2014;7:115-27. <https://doi.org/10.1016/j.jcin.2013.10.012>
2. Bapat VN, Davies W, Attia R, Hancock J, Bolter K, Young C, et al. Use of balloon expandable transcatheter valves for valve-in-valve implantation in patients with degenerative stentless aortic bioprostheses: technical considerations and results. *J Thorac Cardiovasc Surg.* 2014;148:917-24. <https://doi.org/10.1016/j.jtcvs.2014.05.029>
3. Bapat VN, Attia RQ, Condemni F, Visagan R, Guthrie M, Sunni S, et al. Fluoroscopic guide to an ideal implant position for Sapien XT and CoreValve during a valve-in-valve procedure. *JACC Cardiovasc Interv.* 2013;6:1186-94. <https://doi.org/10.1016/j.jcin.2013.05.020>
4. Doenst T, Amorim PA, Al-Alam N, Lehmann S, Mukherjee C, Faerber G. Where is the common sense in aortic valve replacement? A review of hemodynamics and sizing of stented tissue valves. *J Thorac Cardiovasc Surg.* 2011;142:1180-7.
5. *Cardio Valve App.* Rotterdam, The Netherlands: DigiMedNet BV; 2012.
6. Tam DY, Dharma C, Rocha RV, Ouzounian M, Wijeyundera HC, Austin PC, et al. Early and late outcomes following aortic root enlargement: a multicenter propensity score-matched cohort analysis. *J Thorac Cardiovasc Surg.* 2020;160:908-19.e15. <https://doi.org/10.1016/j.jtcvs.2019.09.062>
7. Manouguian S, Seybold-Epting W. Patch enlargement of the aortic valve ring by extending the aortic incision into the anterior mitral leaflet. *J Thorac Cardiovasc Surg.* 1979;78:402-12. [https://doi.org/10.1016/s0022-5223\(19\)38105-x](https://doi.org/10.1016/s0022-5223(19)38105-x)
8. Nicks R, Cartmill T, Bernstein L. Hypoplasia of the aortic root. The problem of aortic valve replacement. *Thorax.* 1970;25:339-46.
9. Yang B. A novel simple technique to enlarge the aortic annulus by two valve sizes. *J Thorac Cardiovasc Surg Tech.* 2021;5:13-6.

10. Lederman RJ, Babaliaros VC, Rogers T, Khan JM, Kamioka N, Dvir D, et al. Preventing coronary obstruction during transcatheter aortic valve replacement: from computed tomography to BASILICA. *JACC Cardiovasc Interv.* 2019;12:1197-216.
11. Davierwala PM, Borger MA, David TE, Rao V, Maganti M, Yau TM. Reoperation is not an independent predictor of mortality during aortic valve surgery. *J Thorac Cardiovasc Surg.* 2006;131:329-35.
12. Deharo P, Bisson A, Herbert J, Lacour T, Etienne CS, Porto A, et al. Transcatheter valve-in-valve aortic valve replacement as an alternative to surgical re-replacement. *J Am Coll Cardiol.* 2020;76:489-99.
13. Webb JG, Murdoch DJ, Alu MC, Cheung A, Crowley A, Dvir D, et al. 3-year outcomes after valve-in-valve transcatheter aortic valve replacement for degenerated bioprostheses. *J Am Coll Cardiol.* 2019;73:2647-55.
14. Blackman DJ, Saraf S, MacCarthy PA, Myat A, Anderson SG, Malkin CJ, et al. Long-term durability of transcatheter aortic valve prostheses. *J Am Coll Cardiol.* 2019;73:537-45.
15. Edelman JJ, Shults C, Thourani VH. Transcatheter aortic valve replacement valve durability: good enough for young, low-risk patients? *J Thorac Cardiovasc Surg.* 2020;159:1249-55.
16. Bapat VN, Zaid S, Fukuhara S, Saha S, Vitanova K, Kiefer P, et al. Surgical explantation after TAVR failure: mid-term outcomes from the EXPLANT-TAVR International Registry. *JACC Cardiovasc Interv.* 2021;14:1978-91.

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