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Society Position Statement

2019 Canadian Cardiovascular Society Position Statement for Transcatheter Aortic Valve Implantation

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ABSTRACT

Transcatheter aortic valve implantation (TAVI) or replacement has rapidly changed the treatment of patients with severe symptomatic aortic stenosis. It is now the standard of care for patients believed to be inoperable or at high surgical risk, and a reasonable alternative to surgical aortic valve replacement for those at intermediate surgical risk. Recent clinical trial data have shown the benefits of this technology in patients at low surgical risk as well. This update of the 2012

RÉSUMÉ

L'implantation valvulaire aortique par cathéter (TAVI) a rapidement modifié le traitement des patients atteints de sténose aortique symptomatique grave. Elle constitue maintenant la norme de soins chez les patients jugés inopérables ou présentant un risque chirurgical élevé, de même qu'une solution de rechange raisonnable à la chirurgie de remplacement valvulaire aortique en présence d'un risque chirurgical intermédiaire. Les données d'essais cliniques récents ont aussi

Aortic stenosis (AS) is the most common valvular heart disease in elderly patients, with increasing prevalence worldwide.[1] Initially considered experimental, transcatheter aortic valve implantation (TAVI) or replacement (TAVR) has transitioned rapidly to the standard of care for inoperable patients with symptomatic severe AS and those at high surgical risk.[2] In 2012, the Canadian Cardiovascular Society (CCS) published its first position statement for TAVI.[3] This update is on the basis of new evidence that has become available since 2012, with the goal of providing guidance to Canadian programs in which patients with severe AS are treated and to address the unique challenges they face in terms of access to care, funding for interventions, infrastructure availability for program management and data collection, and support for patient preference in therapeutic decision-making.

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The disclosure information of the authors and reviewers is available from the CCS on their guidelines library at www.ccs.ca.

This statement was developed following a thorough consideration of medical literature and the best available evidence and clinical experience. It represents the consensus of a Canadian panel comprised of multidisciplinary experts on this topic with a mandate to formulate disease-specific recommendations. These recommendations are aimed to provide a reasonable and practical approach to care for specialists and allied health professionals obliged with the duty of bestowing optimal care to patients and families, and can be subject to change as scientific knowledge and technology advance and as practice patterns evolve. The statement is not intended to be a substitute for physicians using their individual judgement in managing clinical care in consultation with the patient, with appropriate regard to all the individual circumstances of the patient, diagnostic and treatment options available and available resources. Adherence to these recommendations will not necessarily produce successful outcomes in every case.

Methods

This document was developed in accordance with CCS best practices and in accordance with the Framework for Application of Grading of Recommendations, Assessment, Development, and Evaluation (see https://www.ccs.ca/images/Development_Process/CCS_GRADE_Framework_June2015.pdf for details). A systematic review of the literature was performed to evaluate TAVI program considerations, patient selection, and procedural and postprocedure guidelines. The primary panel voted on all recommendations and acceptance was defined as agreement of two-thirds of the

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Canadian Cardiovascular Society TAVI position statement incorporates clinical evidence to provide a practical framework for patient selection that does not rely on surgical risk scores but rather on individual patient evaluation of risk and benefit from either TAVI or surgical aortic valve replacement. In addition, this statement features new wait time categories and treatment time goals for patients accepted for TAVI. Institutional requirements and recommendations for operator training and maintenance of competency have also been revised to reflect current standards. Procedural considerations such as decision-making for concomitant coronary intervention, antiplatelet therapy after intervention, and follow-up guidelines are also discussed. Finally, we suggest that all patients with aortic stenosis might benefit from evaluation by the heart team to determine the optimal individualized treatment decision.

montré les avantages de cette technologie dans un contexte de faible risque chirurgical. Cette mise à jour de l'énoncé de position sur le TAVI publié en 2012 par la Société canadienne de cardiologie (SCC) intègre des données cliniques probantes constituant un cadre de référence pratique pour la sélection des patients, fondé non pas sur le score de risque chirurgical, mais plutôt sur l'évaluation individualisée des risques et des avantages respectifs de l'intervention TAVI et de la chirurgie de remplacement valvulaire aortique chirurgicale. En outre, cet énoncé de position intègre de nouvelles catégories de temps d'attente et de nouveaux objectifs en matière de calendrier de traitement pour les patients sélectionnés en vue d'une intervention TAVI. Les exigences des établissements et les recommandations en matière de formation et de maintien des compétences des chirurgiens ont également été révisées de manière à refléter les normes courantes. Diverses considérations liées à l'intervention sont également examinées, notamment la prise de décisions touchant une intervention coronarienne concomitante, la mise en route d'un traitement antiplaquettaire après l'intervention et les lignes directrices en matière de suivi. Enfin, nous abordons le concept d'une évaluation effectuée par l'équipe de cardiologie qui permettrait d'optimiser les décisions thérapeutiques sur une base individuelle et qui pourrait s'avérer avantageuse dans tous les cas de sténose aortique.

panel members. The recommendations and the complete document were then reviewed by a secondary panel and the CCS Guidelines Committee.

This document is divided into 3 sections: TAVI program considerations, patient selection and specifics regarding the procedure, and patient follow-up.

TAVI Program Considerations

TAVI penetration and wait times

At this time, there are 28 TAVI centres in Canada. Despite the growth in TAVI demand, available data suggest that TAVI remains relatively underutilized on the basis of estimates of penetration obtained from data in the CCS TAVI Quality Report (2014-2017), despite an increase from 34 to 47 cases per million population.[4] In comparison, the rates of TAVI in Europe have increased dramatically from 38 per million in 2011 in France to 155 per million in 2016.[5] The penetration rate is a metric of use of that therapy among eligible patients and is a measure of actual TAVI use relative to potential use. Penetration rates in Canada have been low compared with that in western European countries and the United States because of different regulatory and funding challenges. Rates have improved over time, although the gap remains similar. For the high-risk indication, it is estimated that there are approximately 6826 TAVI candidates annually in Canada on the basis of a population rate of 195 cases per million.[6] If the indication for TAVI expands to the low-risk population, this number should increase to 10,516 potential candidates annually on the basis of a population rate of 300 cases per million. The optimal number of procedures for a country or given region is unknown; however, what is clear is that patients deemed appropriate for TAVI should have equitable access to care within a reasonable period of time.[4]

Nonetheless, data from the 2016 CCS TAVI Quality Report show that across provinces and regions, there is substantial variation in access to TAVI.[4] Provincial TAVI rates, for example, vary from 24 cases per million in Alberta to 87 cases per million in British Columbia. This difference is likely because of variability in provincial funding for TAVI and the priority given to such procedures in terms of budgetary commitment. TAVI-specific reimbursement systems in Europe are associated with a 3.3-fold higher number of TAVI procedures per million population and 2.5 times more TAVI procedures per centre than constrained systems—those in which there is no specific funding or reimbursement for TAVI (69 ± 18 vs 26 ± 20 implants per centre; $P < 0.008$).[7] It is clear that program sustainability is linked to provincial funding support, which determines the availability of equitable and sufficient access to care for all Canadians.

The lower penetration of TAVI in Canada is accompanied by long wait times that reveal the imbalance between procedural demand and program capacity.

It is imperative that a wait list be maintained at each site; these wait time metrics should be a mandatory performance measure that are collected at each centre.

RECOMMENDATION

Because of the considerable variability in ways in which wait times are measured, we recommend adhering to the following definitions on the basis of the CCS TAVI Quality Indicator document[8]:

a. Total TAVI wait time: date of referral for TAVI to date of procedure.
b. Time to decision: date of referral for TAVI to date of acceptance or documented multidisciplinary heart team decision.
c. Time to treatment: date of acceptance or documented multidisciplinary heart team decision to date of procedure.

Long wait times have negative consequences including patient mortality, morbidity, repeated hospitalizations, and functional deterioration.[9] Data from the initial period of therapy development showed mortality rates of 10%-14% during the waiting period. In Ontario from 2010 to 2016, the cumulative probability of TAVI wait list mortality was 4.3% in a predominantly inoperable and high-risk population, with a relatively constant increase in mortality as wait time increased.[10] There did not appear to be a threshold below which it was "safe" to delay the TAVI procedure.

A follow-up analysis in the post-TAVI reimbursement era showed an estimated median wait time of 80 days that has remained unchanged. The cumulative probability of wait list mortality and heart failure hospitalization at 80 days was unacceptably high—2% and 12% respectively, with a graded increase in events with increasing wait times.[11] Furthermore, patients hospitalized for recurrent symptoms while waiting for TAVI tend to have poorer outcomes after their intervention, suggesting that such patients are at even higher risk and should be given priority. At present, there are no specific benchmarks for TAVI wait times, however, optimal wait times should be dictated not by the technique used to treat a disease, but by the disease itself and the comorbidities that affect survival.

RECOMMENDATION

We recommend the categories of wait list urgency and goals for treatment time (from acceptance to procedure) as shown in Tables 1 and 2. In cases of patients requiring an emergent or urgent TAVR, physicians should carefully consider the risks and benefits of the procedure to avoid futile interventions.

Maintenance of competency

Centres at which TAVI is performed should meet accepted standards to ensure optimal outcomes as outlined in Table 3. First, the availability of on-site cardiac surgery is a requirement for all TAVI centres.[12] Recommended institutional resources include: adequate clinic space with appropriate administrative support; cardiac catheterization laboratory or hybrid operating room with appropriate resources to perform TAVI; imaging facilities for echocardiography and computed tomography (CT); facility to perform permanent pacemaker implantation; and monitored patient facilities for step-down care post-TAVI.

It is well established that increased operator and institutional experience is associated with improved patient outcomes and efficiency. A minimum number of procedures is desirable to minimize complications and maintain optimal results.[13,14] Data from a multicentre international registry has shown significantly increased mortality in centres at which less than 50 procedures per year are performed.[15] Furthermore, a cumulative TAVI experience of at least 225 cases was associated with lower mortality and improved safety outcomes. In more densely populated regions, where access to care would not be compromised, centres of excellence with higher volumes are encouraged because this approach is associated with still better outcomes.[13] A recent analysis of the Transcatheter Valve Therapy (TVT) registry of more than 113,000 TAVI procedures between 2015 and 2017 showed a significant inverse association between annualized volume of transfemoral TAVR procedures and mortality. In particular, there was a reduction in mortality of 19.5% between high-volume TAVI centres (median of 143 procedures per year) vs low-volume centres (median of 27 procedures per year). In addition, there was a reduction in patient mortality of 24% between higher- (median of 70 procedures per year) and lower- (median of 10 procedures per year) volume operators.[16]

Table 1. Wait time categories and goals for treatment times

Wait time category	Description	Treatment goal
Emergent	Ongoing severe respiratory failure or hemodynamic instability	≤ 48 Hours
Urgent	Inpatient or recent hospitalization with ongoing NYHA III-IV symptoms, related to valve disease or other life-prolonging medical/surgical treatment awaiting treatment of severe valve disease	≤ 2 Weeks
Elective	Stable patients	≤ 12 Weeks

NYHA, New York Heart Association.

The previous position statement in 2012 suggested a minimum number of 25 cases per institution per year. Because of the increasing penetration of this technique and expanding indications into lower-risk patient subsets, we recommend as a strict minimum 50 cases per institution annually to maintain competence. In addition, individual operator experience is paramount to a successful program; therefore, it is important to preserve adequate exposure as either primary or secondary TAVI operator to a strict minimum of 50 cases annually.

In addition to the institutional resources specified, the presence of a multidisciplinary heart team is a requirement for all TAVI programs. Although there is a low level of evidence, the heart team approach is widely endorsed in all international guidelines as a strong recommendation. The primary purpose is to leverage multidisciplinary expertise to guide the management of patients with complex severe valvular heart disease. At a minimum, the heart team should be comprised of an interventional cardiologist and a cardiac surgeon who share expertise in the management of complex structural heart disease. The additional contributions of imaging specialists (CT radiology and echocardiography) and nursing, as well as anaesthesiology, heart failure specialists, geriatricians, and internal medicine augment the multidisciplinary expertise. The patient is at the centre of any decision-making paradigm. To that end, we recommend the incorporation of the patient and their preferences in the decision-making process and suggest the implementation of shared decision-making tools, such as the American College of Cardiology Aortic Stenosis Choice aid (available on acc.org) in the TAVI treatment decision. Because of the recent randomized trial data of TAVI in low surgical risk patients, we strongly suggest that consideration be given to discussing all patients with severe AS in a heart team setting to ensure an optimal treatment decision and patient outcome.[17,18]

Table 2. Summary of recommendations

TAVI Recommendation	Level of evidence
For TAVI programs	
1. We recommend that TAVI should be performed in centres with: a. Experience in high-risk aortic valve surgery b. A strong, collaborative multidisciplinary heart team to guide the treatment decisions of patients referred for evaluation of aortic stenosis	Strong recommendation, medium-quality evidence
2. We recommend that TAVI programs have access to the following: a. Transthoracic and transesophageal echocardiography b. Multislice CT with cardiac gating c. Cardiac catheterization lab or hybrid operating room d. Cardiac surgery e. Perfusion services f. Monitored recovery area g. Critical care unit h. Renal replacement therapy i. Vascular surgery j. Peripheral vascular interventional expertise k. Permanent pacemaker implantation services l. Geriatric evaluation	Strong recommendation, medium-quality evidence
3. We recommend that institutions with TAVI programs perform a strict minimum of 50 cases per year to maintain competency	Strong recommendation, medium-quality evidence
4. We recommend that individual operators perform a minimum number of 50 procedures as either primary or secondary operator annually to maintain competency. In geographical areas with limited procedural volume and resources, the number of operators should be limited to ensure adequate operator exposure and experience, to a minimum of 50 procedures per operator annually to maintain competency of all operators	Strong recommendation, low-quality evidence
5. We recommend that new TAVI operators meet the following minimum requirements: a. Didactic theoretical sessions for 1-2 days b. Simulator training c. Observation of 20 TAVI cases d. Support for the initial 15-20 cases by a proctor or an experienced TAVI operator e. New physicians/surgeons should have performed a minimum 12-month training in TAVI with a minimum of 100 observed TAVI cases with 50 cases as primary operator f. Complete a formal training workshop in CT assessment and interpretation of vascular access and valve sizing	Strong recommendation, low-quality evidence
6. We recommend that a TAVI wait list be maintained at each site and that TAVI wait times be measured according to the CCS TAVI QIs definitions	Strong recommendation, low-quality evidence
7. We suggest that patients accepted for TAVI be triaged according to a system of priority based on their symptoms and that their procedure be performed within the recommended maximum wait-times as shown in Table 1.	Strong recommendation, medium-quality evidence
8. We recommend the measurement of the CCS TAVI QIs at each TAVI program and participation in the CCS TAVI Quality Report initiative as a part of a quality improvement initiative	Strong recommendation, low-quality evidence
Procedural considerations	
1. We recommend that standard evaluation for TAVI patients include the following: a. Comprehensive medical assessment including history and physical b. ECG c. Transthoracic echocardiogram d. Coronary angiography e. ECG-gated CT angiography to evaluate annular dimensions, coronary heights, and vascular access f. Assessment of frailty using the essential frailty toolkit, functional status and quality of life using the Kansas City Cardiomyopathy Questionnaire	Strong recommendation, high-quality evidence
2. We recommend that TAVI should be performed by appropriately trained operators (interventional cardiologist or cardiac surgeon) in a suitable location (hybrid operating room or cardiac catheterization lab) with adequate imaging and patient monitoring capabilities	Strong recommendation, medium-quality evidence
4. We suggest aspirin monotherapy after TAVI unless there is an indication for dual antiplatelet (ie, recent PCI). For patients with an indication for oral anticoagulation we caution against the use of triple therapy (ASA, antiplatelet agent, vitamin K antagonist, or novel oral anticoagulant)	Strong recommendation, medium-quality evidence

ASA, acetylsalicylic acid; CCS, Canadian Cardiovascular Society; CT, computed tomography; ECG, electrocardiogram; PCI, percutaneous coronary intervention; QI, quality indicator; TAVI, transcatheter aortic valve implantation.

Table 3. Key recommended requirements for performing TAVI in Canada according to institution, program, and operator

Institutional requirements for TAVI	Program requirements for TAVI	Operator requirements for TAVI
• On-site cardiac surgery • Cardiac catheterization laboratory or hybrid or with appropriate resources to perform TAVI • Imaging facilities including echocardiography and computed tomography • Facility to perform permanent pacemaker implantation • Monitored patient beds for step-down care • Minimum of 50 cases annually per institution	• Multidisciplinary heart team at minimum comprised of an interventional cardiologist and cardiac surgeon with experience in the management of valvular heart disease • Collection of the CCS TAVI quality indicators • Presence of a monitored wait list • Access to geriatric evaluation	• Minimum of 50 cases annually as primary or secondary operator • Training as per the 2019 CCS position statement recommendations

CCS, Canadian Cardiovascular Society; TAVI, transcatheter aortic valve implantation.

Evaluation of quality of TAVI care

Evaluation of quality of care delivered to TAVI patients is an important component of any TAVI program. In 2016, the CCS TAVI Quality Indicator Working Group published quality indicators for TAVI that focused on structural, process, and outcome measures of quality.[8] The structural components include a heart team treatment recommendation and the collection of TAVI wait times. Process measures focus on evaluation of patient risk and quality of life. Outcome measures include 30-day and 1-year mortality and hospitalization rates as well as in-hospital stroke.

RECOMMENDATION

We recommend that each program maintain the infrastructure and resources to collect and report these indices of TAVI quality on an annual basis to track progress and improvement as well as compare these results with those of other Canadian centres.

Values and preferences. Despite gaps in knowledge with regard to program considerations, these recommendations have been made to focus on improving quality of care for patients who are referred for TAVI by reducing wait times, performing TAVI in appropriate centres with adequate resources and volumes, and monitoring outcomes to deliver a superior quality of care to the patient.

Patient Selection

Because of the long experience and large body of clinical data, surgical aortic valve replacement (SAVR) has been recognized as the standard of care for patients with symptomatic AS. However, more than 15 years have passed since TAVI was introduced,[19] more than 500,000 procedures have been performed worldwide, and more 8000 published reports have clarified the benefits and risks associated with TAVI. Outcomes have steadily improved as a result of advances in technology, techniques, experience, and patient selection. Objective evidence is now available from a large number of comparative analyses and several large randomized trials in which TAVI was compared with the alternatives.

Assessment of surgical risk

TAVI was initially evaluated as an alternative to the established standard of SAVR when the risks of surgery were judged to be prohibitive. Consequently, attention was initially focused on elevated surgical risk as a determinant of candidacy for TAVI. Conditions that increased the risk of surgical mortality, such as advanced age, chronic conditions, previous cardiac surgery, and left ventricular dysfunction were thought necessary criteria for eligibility.

An online calculator developed by The Society of Thoracic Surgeons has been widely used to predict a patient's surgical risk (http://riskcalc.sts.org). For research and regulatory purposes, a risk of all-cause mortality within 30 days after surgery $>$ 8% has been considered "high," 3%-8% "intermediate," and $<$ 3% "low." However, such algorithms do not account for the presence or severity of all comorbidities, nor do they account for the physical or cognitive capabilities that are essential for functional recovery. For practical purposes, the heart team's consensus opinion is more relevant in estimating an individual patient's surgical risk.

Initially, TAVI was evaluated in patients with severe symptomatic AS with a risk profile serious enough to be considered "inoperable." Although medical management alone resulted in a 50% mortality rate at 1 year, TAVI produced a dramatic improvement in symptoms and survival, achieving an absolute 20% improvement in mortality at 1 year in a randomized trial.[20,21] As a consequence, it is generally accepted that TAVI is the current gold standard for suitable patients with severe AS who are declined surgery.

Attention was then directed toward patients at high surgical risk (predicted surgical mortality $>$ 8%), but still considered eligible for SAVR. Randomized comparisons of transfemoral TAVI showed superior or comparable rates of mortality and stroke relative to SAVR.[22-25] Subsequently, randomized comparisons were extended to patients at intermediate surgical risk (mortality rate of 3%-8%). Similarly, transfemoral TAVI was shown to have superior or comparable rates of mortality and stroke relative to SAVR.[26-28] European and American societies have incorporated the results of these trials into practice guidelines.[2,29]

Multiple lines of evidence now document comparable mortality with transfemoral TAVI and SAVR in patients at low surgical risk (predicted surgical mortality < 3%).[30-32] Registry and randomized trial data have shown that, compared with SAVR, TAVI is associated with a lower risk of acute kidney injury, myocardial injury, bleeding, prolonged hospitalization, an earlier hospital discharge, and an improvement in functional status and quality of life.[26,28,33,34] However, TAVI is associated with a higher risk of paravalvular regurgitation, vascular injury, and permanent pacemakers. Recently 2 large randomized trials compared TAVI and SAVR in low surgical risk patients. Both showed that TAVI was associated with lower rates of early death, disabling stroke, blood loss, new atrial fibrillation, and with earlier functional recovery. The Evolut low risk trial met its primary composite end point (death or disabling stroke at 2 years) for non-inferiority.[18] The **P**lacement of **Aor**tic Tra**n**scathe**t**e**r** Valves (PARTNER) 3 trial met its primary end point for superiority of TAVI over SAVR (death, stroke, or rehospitalization at 1 year 8.5% vs 15.1%; $P = 0.001$). In addition, this study showed lower rates of 30-day mortality or stroke (1% vs 3.3%; $P = 0.01$) and similar rates of paravalvular regurgitation, vascular injury, and new pacemakers after TAVI.[17]

The CCS engaged the Canadian Agency for Drugs and Technologies in Health (an independent not for profit organization) to review the available literature on surgical risk as an indication for TAVI. The bulk of available evidence led the Canadian Agency for Drugs and Technologies in Health to conclude that "evidence from systematic reviews and randomized controlled trials showed that, compared to standard therapy or SAVR, TAVI performed mostly via transfemoral route … reduced or maintained the risk of all-cause death, all strokes and rehospitalization rate in patients with severe AS at all levels of risk for open surgery."[35]

Special considerations

Advanced age. Most patients with AS are older adults with multiple chronic conditions and nontrivial surgical risk. In such patients, the less invasive nature of TAVI with its lesser morbidity and shorter recovery times is appealing. Rigourous *in vitro* testing and large clinical and echocardiographic studies have documented comparable durability between TAVI and SAVR devices beyond 5 years.[21,36,37] The available mid-term clinical results for TAVI are promising; however, little is known about the fate of TAVI valves beyond 10 years.

Considerations in younger patients. In younger patients, long-term considerations with TAVI include the potential for more paravalvular regurgitation, permanent pacemakers, less well-documented long-term durability, and difficulty with subsequent selective coronary interventions or cardiac surgery. Younger patients often have bicuspid aortic valves and were excluded from the large randomized controlled trials (see *Assessment of Surgical Risk* section). In contrast, considerations with SAVR include higher transvalvular gradients, increased risk of bleeding and thromboembolism with mechanical valves, and difficulty (in some cases) with subsequent transcatheter valve-in-valve implantation should bioprosthetic surgical valves fail. The relative clinical and patient-reported importance of these concerns might vary. For instance, the presence of right bundle branch block (a risk factor for heart block requiring a permanent pacemaker) or severe subannular calcification (risk factors for paravalvular regurgitation or annular injury) might favour SAVR, whereas the presence of a very small annulus (a risk factor for high transvalvular gradient) might favour TAVI or SAVR with root enlargement or pulmonary autograft (Ross procedure).

It seems reasonable that, in younger patients who undergo SAVR, consideration should be given to whether the proposed surgical bioprosthesis would allow for subsequent "valve-in-valve" TAVI, should the need arise. Surgical bioprostheses that have small internal diameters, externally mounted leaflets, stentless architecture, or are implanted close to the coronary ostia might be unfavourable for valve-in-valve TAVI. Similarly, some TAVI valves that extend above and close to the coronary ostia might not allow for repeat TAVI.

Coronary disease. Coronary artery disease is common in patients with AS. SAVR offers the potential advantage of concomitant aorto-coronary bypass, whereas TAVI offers the option of concomitant or staged coronary angioplasty. However, many patients receive adequate relief of anginal symptoms with SAVR or TAVI alone. Selecting the best revascularization strategy might be best achieved by a heart team consensus.[38,39]

Some patients might be at risk of coronary ostial obstruction because of displacement of diseased native aortic leaflets at the time of TAVI.[40] CT or angiographic screening can identify those at risk. Although there are technical options to mitigate this risk, such patients might be better served by SAVR.

Renal disease. Transfemoral TAVI has been associated with a relatively low risk of acute kidney injury, although patients should be informed of this risk. In the setting of chronic kidney disease, TAVI is associated with lower rates of acute kidney injury and dialysis compared with SAVR and might be the preferred approach.[41] However, end-stage kidney disease, especially in dialysis dependent patients, is a strong predictor of poor late survival and should raise the discussion of futility.[42]

Lung disease. Patients with mild to moderate chronic lung disease can benefit from TAVI and SAVR. Avoiding a thoracotomy and intubation with transfemoral TAVI would appear to be desirable. However, severe lung disease, especially in supplemental oxygen dependent patients, is a strong predictor of poor late survival and limited symptomatic benefit and should raise the discussion of futility.[43]

Liver disease. TAVI, with its lower procedural bleeding risk, might be preferred in patients with early-stage liver disease, and may be performed in patients with more advanced liver disease as a bridge to transplantation. However, very advanced liver disease (eg, Child-Pugh class B or C, especially in combination with renal impairment) is a strong predictor of poor late survival and should raise the discussion of futility.[44]

Peripheral arterial disease. Peripheral arterial disease is generally associated with less favourable early and late

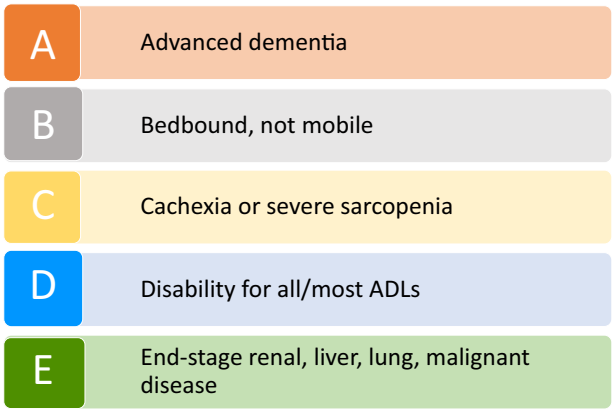

Figure 1. Risk factors that might indicate futility. TAVI may be considered futile and contraindicated if a substantial benefit in terms of quality or duration of life is unlikely. ADLs, activities of daily living. Modified from Afilalo and colleagues[56] with permission.

outcomes after either TAVI or SAVR.[45] Problematic femoral arterial access should prompt the operator to consider alternative access routes (apical, aortic, subclavian, axillary, carotid, caval). However, there are limited data on comparing non-transfemoral TAVI with SAVR. Selecting the best access strategy might be best achieved by a heart team consensus depending on local expertise.

Mitral valve disease. Moderate or severe mitral regurgitation (MR) is common in patients with AS and is associated with less favourable early and late outcomes.[46-48] Secondary MR (due to left ventricular dysfunction) frequently improves after TAVI or SAVR. Primary MR (due to structural abnormalities of the mitral valve) might not improve with aortic valve replacement and when MR is severe, double valve surgery might be desirable. The implications with respect to tricuspid regurgitation might be similar, but this is less well defined. Currently, there is insufficient evidence to recommend a strategy of staged transcatheter multivalve procedures.

Low-flow low gradient AS. Severe AS is often associated with a mean transvalvular gradient of $\geq$ 40 mm Hg. However lower gradients are often encountered in the presence of low transvalvular flow due to left ventricular dysfunction, a small left ventricular cavity, severe MR, or other factors.[49] Surgical risks are increased and TAVI might be preferred in this setting. Impaired left ventricular function in the presence of severe AS should be considered a relative indication, not a contraindication, for TAVI. Left ventricular function often improves after aortic valve replacement, particularly in the absence of ischemic cardiomyopathy. However, extreme left ventricular dysfunction without contractile reserve, particularly in the presence of other comorbidities, should raise the discussion of futility.

Bicuspid aortic valves. Tricuspid aortic valves might become functionally bicuspid as AS progresses, and these are generally amenable to TAVI or SAVR. Of more concern are congenitally bicuspid valves that present in patients at a younger age, sometimes in association with dilation of the ascending aorta and often with bulky eccentric calcification. In patients with low surgical risk and bicuspid aortic valves, SAVR remains the gold standard and offers the opportunity for aortic repair, if indicated. In patients with increased surgical risk, TAVI is often an option although outcomes might be slightly inferior than those achieved with tricuspid AS.

Table 4. Conditions that should be considered by a multidisciplinary heart team when determining the recommendation for transcatheter or surgical aortic valve replacement

	Favours TAVI	Favours SAVR
Risk of surgical mortality or morbidity of intermediate or greater risk (eg, STS score $\geq$ 3)	+	
Advanced age (> 75 years), frailty, limited mobility	+	
Small annulus requiring a small surgical valve (prosthesis size $\leq$ 21 mm)	+	
Longevity unlikely (minimum 2 years required)	+	
Mediastinal anatomy unfavourable for surgery*	+	
Aortic root anatomy unfavourable for TAVI†		+
Advanced atrioventricular block, especially RBBB		+
Nonfemoral access required		+
Congenital bicuspid valve		+
Risk of coronary obstruction or coronary access concerns		+
Pure aortic insufficiency		+
Concomitant conditions requiring surgery (eg, multivalve disease)		+
Aortic aneurysm or dissection		+
Endocarditis		+

RBBB, right bundle branch block; SAVR, surgical aortic valve replacement; STS, Society of Thoracic Surgeons; TAVI, transcatheter aortic valve implantation.

* Porcelain aorta, previous thoracotomy, patent grafts, hostile root.

† Inadequate or excessive calcification, annulus size out of range, coronary obstruction risk.

Failed bioprosthetic valve. When bioprosthetic aortic valves fail, valve-in-valve TAVI is an alternative to reoperation and can often be performed with lower rates of morbidity and mortality.[50-52] A major limitation of valve-in-valve TAVI is that internal dimensions of smaller surgical valves (eg, labelled size $\leq$ 23 mm) might not allow for optimal expansion of transcatheter implants. Coronary obstruction, residual stenosis, and reduced durability of the transcatheter implant is a concern, although this might be mitigated by valve selection or implantation technique. These concerns should be balanced against the benefits of a less invasive procedure.

Pure aortic insufficiency. Initial reports of off-label applications of TAVI for patients with pure severe aortic insufficiency were accompanied by concerning rates of periprocedural complications, particularly in patients with minimal or no cusp calcification. Newer-generation TAVI devices are associated with improved outcomes including lower rates of embolization, migration, need for a second valve implantation, and residual aortic insufficiency.[53,54] SAVR remains the gold standard for patients with pure aortic

Table 5. Long term post-TAVI management

Procedure	Description
Clinical assessment	• 30 Days and yearly
Antithrombotic therapy	• ASA 75-100 mg/d • DAPT for those with recent PCI and indication for DAPT • Oral anticoagulation: NOAC for atrial fibrillation unless contra-indicated* in addition to ASA for TAVI patients; oral anticoagulation for other indications as per standard guidelines
Rhythm assessment	• ECG at 30 days and yearly; consider 24-hour Holter monitor if new bradycardia or heart block
Valve assessment	• Echocardiography at 30 days, 1 year, and as indicated
Concurrent cardiac disease	• Routine management for coronary disease, cardiac risk factors, heart failure, and arrhythmias
Endocarditis prophylaxis	• Encourage optimal dental care and antibiotic prophylaxis per ACC/AHA guidelines
Rehabilitation	• Encourage physical activity and cardiac rehabilitation as appropriate

ACC/AHA, American College of Cardiology/American Heart Association; ASA, acetylsalicylic acid; DAPT, dual antiplatelet therapy; ECG, electrocardiogram; NOAC, novel oral anticoagulant; PCI, percutaneous coronary intervention; TAVI, transcatheter aortic valve implantation.

*Warfarin would be preferable for patients with contraindications to NOACs in the setting of mitral valve stenosis or mechanical valve replacement.

insufficiency, although TAVI is increasingly an option for patients at increased surgical risk.

Frailty. Frailty is a multifactorial geriatric syndrome that predisposes patients to mortality, morbidity, and poor functional recovery, even in cases in which the TAVI or SAVR procedure is technically successful. Frailty should be measured using an objective validated tool such as the Essential Frailty Toolset (frailtytool.com) and integrated into the preprocedural assessment.[55]

Futility. A subset of patients might derive harm from TAVI or SAVR or fail to derive the expected benefits irrespective of the procedure's technical success. The A-B-C-D-E mnemonic might be helpful to identify futile cases with the following risk factors: advanced dementia, bedbound or nonmobile, cachexia or severe sarcopenia, disability for most or all basic activities of daily living, end-stage lung, liver, renal, or malignant disease (Fig. 1).[56] Such patients might be better served by transition to supportive care services to maximize their quality of life.[57] Shared decision-making with the patient, their family members, and the heart team is extremely helpful when faced with these difficult decisions.

Summary of patient selection

Conditions that should be considered when deciding between TAVI and SAVR are summarized in Table 4. Evidence suggests relative equipoise between transfemoral TAVI and SAVR for risk of procedural mortality or stroke. The early benefits of reduced morbidity and rapid recovery with TAVI are appealing, but the late considerations of durability remain a source of uncertainty. The choice between the 2 therapies should depend on the patient-specific risks and technical considerations, as well as the expectations and wishes of the patient and the multidisciplinary consensus of the heart team. Ideally, all patients with symptomatic severe AS would benefit from discussion by the heart team to establish the best treatment on an individual basis.

RECOMMENDATION

We recommend that the choice for TAVI or SAVR be an individualized decision on the basis of consideration of factors or conditions (as shown in Table 4) that might favour one therapy over another. In the setting of relative equipoise between TAVI and SAVR, multidisciplinary team consensus and patients' preferences and values should be taken into account (Strong Recommendation, High-Quality Evidence).

Values and preferences. Because of the current evidence for TAVI in numerous risk groups we believe that the cornerstone of patient selection will rest on identifying patients who will benefit despite their comorbidities and therefore strongly consider medical therapy for conditions that will result in futility. In addition, patients' preferences and values should be an important consideration in the decision-making process.

Procedural Considerations

Preprocedure evaluation

The TAVI procedure requires a number of preparatory evaluations that confirm the clinical indication and anatomical suitability for TAVI. A transthoracic echocardiogram confirms the severity of AS and morphology of the valve. Electrocardiogram (ECG)-gated CT angiography (CTA) is a core element of TAVI procedural planning for accurate prosthesis sizing and prediction and avoidance of cardiac and vascular complications.[58] Systolic reconstruction of the annulus orthogonal to the centre axis of the left ventricular outflow tract allows for the optimal assessment of annular size for valve sizing. CTA also permits careful measurement of the size of the sinuses of Valsalva and sinotubular junction, extent of annular and outflow tract calcification, and the distance of the coronary ostia from the annulus. The iliofemoral anatomy is assessed for size, and the presence of excessive calcification and tortuosity. Evaluation of coronary artery disease is typically done via coronary angiography before the procedure.

Procedure considerations

TAVI should be performed by an appropriately trained operator (interventional cardiologist or cardiac surgeon) in a suitable location (hybrid operating room or cardiac catheterization lab) with adequate imaging and patient monitoring.

Bailout coronary intervention and cardiac surgery should be immediately available, particularly because lower-risk patients are increasingly offered TAVI. A summary of recommendations is presented in Table 2.

Conduct of the procedure

In most cases, TAVI is performed via transfemoral arterial access with a percentage of patients requiring alternative access because of the presence of peripheral vascular disease. Several reports have confirmed a higher rate of death and disabling stroke after nontransfemoral access routes[59] and analysis of randomized trials have indicated benefit of transfemoral access particularly for patients at intermediate risk for SAVR.[26,28] In addition to transapical, transaortic, and trans-subclavian routes, several alternative approaches have been developed including suprasternal innominate, transcarotid, and transcaval.[60-62] These have yet to be evaluated in large series, and choice of alternate access route should be on the basis of patient factors as well as local experience and expertise. If feasible, the transfemoral access route is preferred.

There has been a shift from the practice of general anaesthesia and transesophageal echocardiography during TAVI to a more "minimalist" approach using conscious sedation and local anaesthesia with transthoracic echocardiography guidance, as required. A transition from vascular cutdown to a fully percutaneous approach using closure devices to obtain hemostasis has facilitated this approach and has been shown to be associated with less bleeding and major vascular complications.[63-67] In appropriately selected patients, minimalist TAVI has been associated with improved early outcomes, reduced intensive care unit and hospital length of stay, and reduced cost.[68-70] The decision regarding the use of general anaesthesia and transesophageal echocardiography should be individualized for the patient and depends on local practice and expertise.

Postprocedure care

The simplification and optimization of the TAVI procedure has led to streamlining of postprocedure care in an effort to enhance patient recovery and optimize resource utilization. In the absence of conduction disturbances or immediate vascular complications, well selected patients might recover with minimal or no time in the intensive care unit, and ambulation within 4 hours of the procedure.[71] Early (< 3 days) and next-day discharge have been shown to be feasible and safe,[72-74] with no increased risk of readmission within 30 days or 1 year.[75] As expected, most patients who experienced vascular or bleeding complications, or those who required insertion of a permanent pacemaker were not eligible for early discharge.

Treatment of concomitant coronary artery disease and avoidance of high-risk percutaneous coronary intervention before TAVI

The management of concomitant coronary artery disease in patients who undergo TAVI remains controversial. Because of the progressive nature of coronary artery disease and its high prevalence in patients with severe AS, there will be an increasing need for repeat coronary angiography and percutaneous coronary intervention (PCI) as the indication for TAVI expands to lower-risk patients. Small studies have shown that there might be technical challenges with coronary re-engagement after TAVI, particularly in patients with self-expanding valves that extend above the coronary ostia.[76-79]

Decision-making for PCI before TAVI should focus on the individual patient's clinical condition, anginal symptoms, left ventricular function, lesion location and severity, morphologic complexity and technical feasibility of PCI, and patient preference. The decision to intervene should be made by the multidisciplinary heart team when all circumstances have been considered.

Follow-up

The long-term management of patients after TAVI is similar to those who undergo SAVR, with a few notable differences. Patients who undergo TAVI tend to be older and have more comorbid conditions; the surgical incision is replaced with a percutaneous access site, and the long-term durability of TAVI valves is not yet known. The principles, however, remain the same and are summarized in Table 5. Younger patients and those with expected longevity should have extended follow-up to monitor for late structural valve deterioration.

After TAVI, patients should be transferred to an ECG-monitored bed for a minimum of 4 hours postintervention with telemetry monitoring to identify early conduction abnormalities. Echocardiography before discharge provides a baseline assessment of transcatheter valve function including the mean transvalvular gradient, valve area, assessment of valvular and paravalvular leak, and monitoring of complications of TAVI (valve migration, annular or sinus rupture). Repeat echocardiography at 30 days and then periodically allows for monitoring for long-term complications, guides the management of concurrent cardiac conditions including medical treatment for systolic dysfunction, and tracks the long-term durability of TAVI valves (regurgitation, stenosis, and leaflet calcification or thrombosis). If increasing gradients are observed using transthoracic echocardiography, ECG-gated CTA might be used to evaluate for subclinical leaflet thrombosis, which might occur more commonly than previously suspected. Of note, most reported thromboses could be reversed with oral anticoagulation.[80,81]

The current recommendations for the use of antithrombotic therapy after TAVI are on the basis of expert consensus and the original clinical trial protocols and include clopidogrel 75 mg orally daily for 3-6 months and aspirin 75-100 mg daily lifelong. However, recent data suggest that there is less major or life-threatening bleeding with acetylsalicylic acid alone, with no increase in thromboembolic events.[82,83] In patients with a recent PCI, dual antiplatelet therapy may be continued as per the treating physician. Patients with chronic atrial fibrillation or other indications for long-term anticoagulation should receive anticoagulation per guidelines.[84,85] At present, novel oral anticoagulant therapy for TAVI patients is not recommended without another established indication. It is prudent to avoid triple therapy in patients at increased risk of bleeding.

Conclusion

TAVI is an important treatment option for patients with severe AS. Because of the recent changes and evolving

indications for TAVI in the management paradigm of AS, the current focus should be on improving quality of care by increasing access to therapy, minimizing wait times, and measuring and reporting outcomes to provide optimal patient results.

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