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TAVR in Older Adults:

Moving Toward a Comprehensive Geriatric Assessment and Away From Chronological Age: *JACC* Family Series

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Abstract

Calcific aortic stenosis can be considered a model for geriatric cardiovascular conditions due to a confluence of factors. The remarkable technological development of transcatheter aortic valve replacement was studied initially on older adult populations with prohibitive or high-risk for surgical valve replacement. Through these trials, the cardiovascular community has recognized that stratification of these chronologically older adults can be improved incrementally by invoking the concept of frailty and other geriatric risks. Given the complexity of the aging process, stratification by chronological age should only be the initial step but is no longer sufficient to optimally quantify cardiovascular and noncardiovascular risk. In this review, we employ a geriatric cardiology lens to focus on the diagnosis and the comprehensive management of aortic stenosis in older adults to enhance shared decision-making with patients and their families and optimize patient-centered outcomes. Finally, we highlight knowledge gaps that are critical for future areas of study.

Keywords

aging; biological age; calcific aortic stenosis; chronological age; cognitive function; frailty; patient-centered outcomes; physical function; physiological age; quality of life; TAVR

Calcific aortic stenosis (AS) can be considered a model for geriatric cardiovascular conditions because it encourages the cardiovascular community to realize the limitations of chronological age when assessing suitability of aortic valve replacement in older adults with multiple coexisting geriatric conditions. The remarkable technological evolution of transcatheter heart valves is well documented.[1] Through clinical trials, the concepts of geriatric risk assessments were embedded in the knowledge base of the cardiovascular team, when they were previously only confined to the geriatrics community.[2]

Frailty, a measure of underlying vulnerability in the face of stressors, has now become part of the standard cardiovascular team vocabulary despite the lack of a gold standard assessment.[3,4] The initial focus of frailty was its use in a dichotomous classification,[4] with a goal of identifying the presence or absence of frailty to determine eligibility or futility for a transcatheter aortic valve replacement (TAVR) procedure.[5] A recent study affirmed that a substantial proportion of patients referred for TAVR procedures showed objective evidence of frailty.[6] In addition, and irrespective of procedural success, this conferred a 50% risk of mortality or poor quality-of-life at 1 year.[6] It is now evident that optimal care for older adults with cardiovascular diseases needs a more comprehensive approach than a simple dichotomous assessment of frailty.[4,7–10]

The well-known adage often quoted by geriatricians, "if you have seen one 85-year-old… you have seen one 85-year-old," further fuels the shift away from a solitary focus on chronological aging towards the necessity of a more thorough evaluation. The heterogeneity of older adults living in the community and in those referred for TAVR is often evident to clinicians but it can be quantified and its nuances explored with the performance of a comprehensive geriatric assessment (CGA).[11] The CGA, a cornerstone in the geriatricians' toolkit, gathers information on various factors like medical, physical, cognitive, social, and financial conditions that might adversely affect mortality and quality of life.

The current difficulty, however, is in operationalizing the CGA. The components of the CGA are often time-consuming, creating problems in situations in which the clinical workforce is stretched thin. The recently developed CGA-frailty index (FI),[12] a global estimate of the physiological status in older adults, combines 2 important geriatric precepts: the CGA and frailty. Initial validation and single-center use have demonstrated the potential of the CGA-FI to be performed by the cardiovascular team. This review highlights important geriatric cardiology principles that should guide the cardiovascular community at large to optimally care for the diverse population of older adults referred for TAVR evaluation.

CHRONOLOGIC VS BIOLOGIC AGING

Chronological aging refers to the time-dependent decline in physical and biologic functions from the time of birth until senility.[13] The observation that this decline occurs at different rates among patients led to the concept of biologic aging because the age-associated decline is the result of the interplay between genetics, biology, and environmental factors.[14] Biological aging refers to the individual's variability in the age-associated declines in function as a construct with variable effects on individuals as they age.[13,14]

AS IN OLDER ADULTS

AS is the most common valvular heart disease among older adults. While the majority are either calcific or degenerative, rheumatic and bicuspid aortic valve etiologies occur to a much lesser extent. The prevalence of AS increases with age; approximately 12% of adults aged 75 years or older have some degree of AS, and 3.4% have severe symptomatic AS.[15] In 2019, it was estimated that 9 million people had moderate-severe AS, a 17-fold increase in the prevalence over the last 30 years.[16] In the PARTNER trial when TAVR was initially examined, the mean age of the patients who could not undergo conventional cardiac surgery was 83 years.[17] Since then, the median age of patients in practice has been between 81 and 84 years.[18] Because most of TAVR procedures are performed in older patients, the cardiology community needs to rethink its approach to the TAVR procedures in older patients. Understanding AS as a model for geriatric cardiovascular conditions emphasizes the impact of concomitant geriatric conditions beyond the specifics of the aortic valve. In the management of these patients, other cardiovascular abnormalities need to be considered as do the presence of dominant morbidities such as chronic kidney disease, dementia, heart failure (HF), and obstructive lung disease.[7] Geriatric conditions may obscure symptom presentation and complicate prognostication. The classic association of angina, syncope, and HF with all-cause death at intervals of 5, 3, and 2 years, respectively, may be different when accounting for geriatric risks.[19] The presence of multimorbidity, frailty, physical inactivity, and cognitive dysfunction all act as confounders on symptoms and prognosis in AS and undoubtedly influence the current estimates that almost 25% of older patients with severe AS are asymptomatic.[20] Further study is needed to deteremine whether this represents a true absence of symptoms, a disease adaptation, or obfuscation due to the presence of geriatric conditions.

Noninvasive multimodal imaging is central in the diagnosis and management of all patients with AS. While transthoracic echocardiography and cardiac computed tomography (CT) are the predominant techniques for diagnosing and managing patients with AS prior to TAVR, both transesophageal echocardiography and cardiac magnetic resonance (CMR) imaging can be used in select cases. Exercise testing may unmask symptoms and is recommended for risk stratification in asymptomatic patients with severe AS because it provides additional prognostic information by assessing the increase in mean pressure gradient and change in left ventricle (LV) systolic and diastolic function. Progressive AS results in left ventricular hypertrophy, myocardial fibrosis, decrease in coronary flow reserve, pulmonary hypertension, changes in LV compliance, and eventually, a decrease in systolic function. Myocardial fibrosis, a major contributor to LV decompensation in AS, can be measured using CMR and may be reflected in echocardiographic global longitudinal strain imaging.

The 2020 American College of Cardiology/American Heart Association guidelines classify AS in 4 stages [A (at risk), B (progressive, mild to moderate, asymptomatic), C (severe, asymptomatic), and D (severe, symptomatic)]. Stage D, symptomatic severe AS is particularly important in older adults and is divided into the following 3 further stages: D1 (high gradient), D2 (low-flow, low gradient, low left ventricular ejection fraction [LVEF]), D3 (low-gradient, normal LVEF also called paradoxical low-flow severe AS). For older adults suspected of having low-flow, low-gradient severe AS, with normal or reduced LVEF (stages D2 and D3), calculating the ratio of the outflow tract to aortic velocity time integral and measurement of aortic valve calcium score by CT imaging can be helpful to further define the severity of the disease. CT imaging thresholds for severe AS in Agatston units have been validated and are as follows: men >3,000, women >1,600 = highly likely; men >2,000, women >1,200 = likely; men <1,600, women <800 = unlikely. The applicability of using CT in very old adults may need further study.

Cardiac amyloidosis is often diagnosed in older patients who present with HF with preserved ejection fraction. The prevalence increases with age and, among those 65 years or older, transthyretin cardiac amyloidosis is diagnosed in 4% to 16% of AS cases referred for TAVR.[21–23] When AS is encountered concomitantly with cardiac amyloid, the diagnosis using echocardiography alone can be challenging.[24] The sensitivity in detecting cardiac amyloid is improved with bone scintigraphy, CMR imaging, and endomyocardial biopsies.[24] While hospital mortality and 30-day rehospitalization after TAVR procedure is similar between those with cardiac amyloid and severe AS vs those with severe AS only, the presence of cardiac amyloid has a 3-fold increase in the odds of developing stroke during index hospitalization.[24] Both groups show marked symptomatic improvement post-TAVR. For AS-ATTR cardiac amyloid, TAVR reduced the LV end diastolic and end-systolic volumes, improved the degree of concomitant mitral regurgitation, and resulted in improvement in systolic function.[25] One study found transthyretin cardiac amyloidosis in 16% of patients with severe calcific AS undergoing TAVR, which was associated with low-flow low-gradient, and mildly reduced ejection fraction.[18] When cardiac amyloidosis is clinically suspected, based on symptoms (neuropathy), hematologic data, or electrocardiogram findings (low voltage or absence of left ventricular hypertrophy), nuclear imaging with bone avid tracers such as technetium pyrophosphate should be considered. Amyloidosis often persists following valve intervention and is associated with poor long-term prognosis.[18–20] It is important to diagnose cardiac amyloid because it can be treated with tafamadis and other emerging therapies.

COMPREHENSIVE GERIATRIC ASSESSMENT

We pose 2 questions addressing an approach to care for older adults with AS being considered for TAVR. The first: Will the knowledge and heightened awareness of geriatric risks—gathered through a frailty and CGA—influence the planned cardiovascular care? The second: Can the cardiovascular team take the time to address some of the geriatric risks for older patients? For instance, referring a patient for cognitive evaluation when family or caregivers express concerns with memory is often needed. Contemporary valvular heart disease guidelines contain limited insights on the spectrum of geriatric conditions that can potentially impact periprocedural TAVR care in older adults.[20] While the cardiovascular risks of TAVR are well documented, evidence is lacking on the effect of geriatric conditions on short and long-term outcomes. Current patient-level evaluation of harm consists of acknowledging the presence or absence of severe comorbidities, physical disability, eg, measured by Katz activities of daily living questionnaire, and decreased gait speed.[20] Additionally, guideline recommendations for considering futility (eg, Society of Thoracic Surgery score>15, life expectancy <1 year, poor candidacy for rehabilitation, advanced dementia, and comorbidity burden) are based on expert opinion without primary research to examine feasibility and impact on patient outcomes.[5]

The concept of frailty, currently well integrated within the cardiovascular literature, was highlighted and disseminated to the cardiovascular community by the initial landmark TAVR trials.[1] While clinical trials have led to the robust procedural development of TAVR, it is important to recognize that registry data may better track the specifics of frailty, multimorbidity, cognitive and physical function, malnutrition, as well as the utility of biomarkers in relation to progressive aortic valve stenosis as well as patient-centered outcomes after TAVR. As frailty has been associated with suboptimal healthcare outcomes, several well-validated tools have been created for risk prediction. These tools have utilized a combination of objective estimates, and we point readers toward reviews focused in this area.[4,26] The Essential Frailty Toolset, developed and validated in patients with severe AS, had the highest accuracy in predicting mortality among the instruments studied and is feasible to implement even in a busy clinical setting.[27]

The CGA is a complete and holistic evaluation of physical health (vision, hearing, multimorbidity, polypharmacy, nutrition, balance/falls), functional status (basic and instrumental activities of daily living, Nagi-Rosow-Breslau functional health scale), neuro-cognitive status and mood (cognition, delirium, mood/depression, grief), and socio-environmental status (financial, risk for elder abuse, caregiver stress, living environment). This core tenet of geriatric care, obtained through a systematic evaluation, may improve risk stratification prior to TAVR and may identify opportunities for risk mitigation.[28] The cardiovascular team is encouraged to become familiar with the domains of the CGA as these have the potential to have a meaningful impact on cardiovascular and noncardiovascular outcomes.[29,30] Moreover, whether improving or modifying domains of the CGA through targeted interventions prior to a cardiovascular intervention such as TAVR improves outcomes is an active area of investigation (NCT03107897). Below we highlight several components of the CGA that may be most pertinent to older patients presenting with severe AS being considered for TAVR. However, we recognize that this geriatric survey is a means to gather the evidence, and the clinical team will need to decide which components are most applicable to the clinical settings.

CAREGIVER BURDEN.

The context of care delivered to older adults undergoing TAVR workup should be considered in the framework of the patient-caregiver dyad or patient-caregiver-family triad. The spouse is usually the first person looked on to help with caregiving. The job of caregiving is an arduous task, often associated with high levels of depression in the caregiver. Sex based differences in the prevalence of depression has been noted with higher caregiver burden felt mostly by women. The underlying predisease level of marital disagreement has been noted to be closely associated with greater mood disorders in the caregiver. Recognition of transitions in care (hospital-to-home, hospital-to-short term rehabilitation facility, and others) is particularly traumatic to the dyad or triad unit. A feeling of unpreparedness is commonly reported while others only experience unpreparedness when a care failure occurs. Based on these data, which are limited in the setting of TAVR, cardiovascular teams should consider how to optimize communication tools needed during this stressful time such as discharge instructions.[31] This should be done taking into consideration patient and caregiver native language and education level achieved.[32]

FALLS.

Falls are often under recognized by clinical teams. In the context of severe AS in older adults, falls may be attributed to the severity of AS or other concomitant cardiovascular abnormalities. However, nonsyncope related falls in older adults may also be a symptom of frailty, sarcopenia, sensory and cognitive impairment, and environmental hazards.[33] Awareness of this important geriatric syndrome may lead cardiovascular team members to take an initial action (referral for home hazard reduction, physical and/or occupational therapy, nutritional consultation) to aid in the potential mitigation of future events.[34]

GASTROINTESTINAL, GENITOURINARY, SLEEP, PAIN, AND SUBSTANCE USE.

These common conditions can impact patient-centered outcomes post TAVR. A knowledge of urinary incontinence may necessitate (1) discussion of the timing of diuretics with the nursing staff; (2) consideration of appropriate use of overactive bladder medication; or (3) offering targeted toileting and providing adult briefs/diapers overnight and at discharge rather than the placement of a urinary catheters. Recognition of the constipation and use of prevention and treatment strategies can prevent bladder obstruction, delirium, and reduced quality of life in the postoperative period.

Aging is associated with changes in sleep. A higher frequency of daytime naps, delay in sleep onset, decreased amounts of deep sleep, greater wakefullness all contribute to insomnia in the older adults. Older adults undergoing TAVR may use sleeping aids, either over the counter preparations or prescribed agents such as zolpidem, many of which are high risk for delirium during TAVR admission, or falls and other adverse effects after discharge. The preoperative TAVR evaluation period may be an opportune time to review of these potentially inappropriate medications, although whether this improves outcomes is unknown Given the high prevalence of obstructive sleep apnea as well as impaired sleep, older adults with sleep difficulties should be referred for workup.[35]

The prevalence and complexity of pain in older adults considered for TAVR is not known. Evaluation of pain characteristics in the context of psychological, biological, and social factors with referral to geriatrics or pain specialty can be considered. Relatively, substance use in older adults is increasing in the United States and is often unrecognized, and the associated multimorbidity and polypharmacy renders interactions with unhealthy substance use a higher risk of harm particularly with the use of psychoactive substances. Numerous screening tools are available such as the Alcohol Use Disorders Identification Test, Michigan Alcohol Screening Test-Geriatric version have been identified to be useful in older adults and we recommend readers to standard references in this area.[36,37]

HEARING LOSS.

Hearing loss has been identified as a substantial, modifiable, risk factor for the occurrence of dementia and depression, with a 63% prevalence in adults over 70 years. In older patients with cardiovascular disease, the role of hearing loss is particularly important while discussing the consent process for the TAVR procedure, goals of care, prevention of delirium during TAVR admission, and understanding the discharge instructions.[38] It is often treatable with hearing aids. The relationship between hearing and cognitive function is complex with some studies showing the prevention of incident cognitive impairment while others suggesting an attenuation of the onset of dementia.

MALNUTRITION.

Malnutrition is a major predictor of poor outcomes in older patients undergoing surgical aortic valve replacement (SAVR) or TAVR.[39] However, there is no universally accepted definition of malnutrition. The American Society of Parenteral and Enteral Nutrition defines malnutrition as having 2 of the following—insufficient energy intake, loss of muscle mass, fluid accumulation, weight loss, loss of subcutaneous fat, and diminished function by handgrip strength. The Global Leadership Initiative on Malnutrition includes 1 etiologic criterion (decreased food intake, increased disease burden) and 1 or more phenotypic criteria (nonintentional weight loss, low body mass index, reduced muscle mass). The presence of malnutrition was associated with higher periprocedural adverse events and 1-year mortality with the combination of frailty and malnutrition having an even higher mortality rate.[39] Formal nutritional assessment may standardize the evaluation. The Mini-Nutritional Assessment-short form is a tool that is scored from 0 to 14 points with lower scores indicating a higher risk of malnutrition. It asks questions concerning total food intake, weight loss in prior 3 months, mobility, neuropsychological findings, body mass index. Taken together, risks of malnutrition after TAVR is an indicator of poor prognostic risk for mortality and HF hospitalization, and a focus on improving nutritional status may have positive implications for older patients after the TAVR procedure.[40]

SARCOPENIA.

Sarcopenia, a condition of progressive loss of muscle mass and function, can further thwart expected progress after TAVR.[33] In 1 study, the combination of sarcopenia, as defined by low muscle mass and strength combined with frailty measured by decreased chair-rise performance (5 unassisted sit-to-stands in ≥15 seconds) was noted in 21% of patients with AS and was associated with increased mortality, disability, and discharge to skilled nursing facility. Moreover, significant differences in outcomes between the sexes have also been noted with women being more physically frail before TAVR and with greater deconditioning post procedure compared to men.[41] Physical mobility is also critical as it enables the engagement in daily activities, maintenance of independence, and continued participation in social interactions. Furthermore, the triad of malnutrition, frailty, and sarcopenia is not only common but poses an incrementally worse clinical outcome.[39]

COGNITION.

Deterioration in cognition and mood plays a pivotal role in limiting quantity and quality of life for older adults with AS.[42] Deficits in cognitive domains (learning and memory, language, visuospatial, executive function, attention, social cognition) resulting from mild cognitive impairment (driven by short-term memory loss and executive dysfunction) or more severe forms such as major cognitive impairment or dementia may underlie limitations in making informed decisions, maintaining independence, and engaging in meaningful relationships. Cognitive dysfunction at baseline has been associated with longer hospital stays, greater probability of transition to a postacute rehabilitation facility, and in-hospital delirium. It has been shown to be an independent predictor of mortality at 1-year post-TAVR in 1 study, but in-hospital mortality was similar to those with no cognitive function.[43] Addressing cognitive function with initial screening tools like the Alzheimer's dementia 8 can lead to implementing bedside tools like the Mini-Cog or more sophisticated tools like Montreal Cognitive Assessment or Mini-Mental Status Examination to further quantify the extent of cognitive dysfunction which may result in altering the course of the management plan. Specifically, those with dementia are at the highest risk of in hospital delirium which is associated with poor outcomes after TAVR and may be preventable with interventions such as the Hospital Elder Life Program (Table 1).[52,53]

MOOD DISORDERS.

Mood changes, such as depression and anxiety also play a pivotal role in the inability to achieve an optimal quality of life for older adults with AS. The prevalence of depression in older patients with AS can be as high as 24% and has been associated with increased mortality. Although in 1 study, depression and anxiety improved after TAVR the measurement tool (Patient Health Questionnaire-2) may be insufficient, and further granularity is needed. The FRAILTY-AVR (Frailty in older adults undergoing aortic valve replacement) observational study showed that at baseline 31.5% screened positive by the Geriatric Depression Scale Short Form. The prevalence in those undergoing TAVR was 33.8% and those undergoing SAVR was 27.5%. Baseline depression was associated with higher risk of 1-month and 1-year mortality. However, the link between baseline depression and excess mortality has been hypothesized to be possibly due to apathy or impaired executive function, which can mimic depression; further study is needed.

Other components of CGA include functional status, polypharmacy, multimorbidity, and sensory impairment—specifically visual impairment, and are addressed by the geriatric cardiology team because they can influence the long-term management of older adults after TAVR.[9,54] A full discussion on the use of CGA in the management of older adults with cardiovascular disease is discussed in detail elsewhere.[54]

PUTTING IT TOGETHER: CGA-FI

We believe the time has come for the CGA to be considered the standard within the cardiovascular community in the care of complex older adults (Central Illustration). This is founded on the appreciation of frailty as an important geriatric precept.[2] Furthermore, recently described recognition of the morbidity and mortality implications of geriatric conditions such as falls,[9] sarcopenia,[55] cognitive and physical dysfunction,[7] malnutrition,[56] and other incident or prevalent geriatric conditions has begun to be well-entrenched in the geriatric cardiovascular literature but continues to experience a slow uptake in the community.[7,57,58]

Incorporating an online tool that integrates important portions of a CGA along with physical frailty evaluations can potentially standardize the pre-TAVR workup in older adults. While there are many tools available,[3] a recently developed online CGA-FI calculator integrates CGA components into a numerical frailty index. This well-validated tool has been shown to identify patients least likely to experience overall functional improvement following TAVR.[11]

The CGA-FI approach to measuring frailty is a summary score of deficits in health that are counted and divided by the total number of deficits assessed.[59] What differentiates a CGA-FI from a comorbidity index is that it includes evaluation of cognitive and physical function, sensory impairment, nutritional status, mood, and other domains of health in addition to chronic medical conditions. The calculator requires evaluation of at minimum 21 medical history components and 22 functional questions, with additional options of including cognitive and performance tests (https://www.bidmc.org/research/research-by-department/medicine/gerontology/calculator). Passive versions of a CGA-FI that extract clinical data from an electronic health record have been developed.[29,60,61] These are best used for screening and should be followed with an in-person assessment during follow up for formal cognitive evaluation. All other features should take <5 minutes. Once a score has been generated, a radar plot identifies which health domains are vulnerable, allowing clinicians an opportunity to develop a differential diagnosis for each and a prescription for care. The utilization CGA-FI should be part of the multidisciplinary Heart Team approach when evaluating older adults undergoing TAVR. It should be noted that preparing the frail older adult for TAVR starts from the preprocedural period, which facilitates easier postprocedural care and outpatient management.

WHAT MATTERS MOST?

Optimal pairing of older adults with severe AS to TAVR requires considering patient priorities, values, and preferences.[62] This patient-centered care approach can be further expanded by understanding post-TAVR expectations of physical goals (Table 2). Physical goals, such as a post-TAVR dream of running a marathon (stated purposely in an exaggerated manner), will be unrealistic when the current physical activity status is poor.[11]

The next step is to ‘first do no harm’. This guiding principle emphasizes the importance of patient safety and well-being in the practice of medicine. An understanding of post-TAVR physical goals, in a Specific, Measurable, Achievable, Relevant and Time-Limited (SMART) manner is extremely relevant to the guiding principle. SMART, borrowed from the quality initiative movement, is a nonspecific tool to better quantify physical function goals. An understanding of patient’s physical goals by receiving a quantitatively friendly response can aid in the discussion of whether the potential benefits can outweigh the potential harms. For example, when asked regarding physical goals a patient may answer as follows: “I would like to walk 5 days a week, 1 mile each time, with my spouse and my dog.” This is a SMART answer. It is specific, measurable, achievable (based on the clinical context), relevant (not exaggerated), and time-dependent (and can change if overall condition worsens or improves).

IMPORTANCE OF CODE STATUS DISCUSSIONS

Despite recommendations from the Centers for Medicare & Medicaid Services and professional societies promoting shared decision-making for TAVR, current guidance does not address management of do not resuscitate (DNR) status. This is especially important as the population continues to age and DNR preference becomes more prevalent.[63,64] Most older adults with severe AS present for TAVR evaluation to improve quality of life,[65] making cardiopulmonary resuscitation no longer the presumed default. Older adults with multimorbidity and frailty are more likely to experience adverse outcomes[11,27,66] and decreased quality of life not only postprocedurally, but also following cardiopulmonary resuscitation for in-hospital cardiac arrest.[67–69]

INTEGRATING PATIENT AND FAMILY PREFERENCES.

Marked heterogeneity exists in management of peri-procedural code status across TAVR programs (Figure 1). According to a recent study, nearly all (96%) TAVR programs addressed periprocedural code status, yet only one-quarter (26%) had established policies.[69] While most programs (78%) required temporary suspension of DNR, time frames for reinstatement varied substantially. Among programs categorically reversing patients' DNR status, rationale for differing lengths of time to reinstatement reflected divergent views on accountability and reporting requirements. Although marked variability in code status practice exists, no clinically substantial differences by code status practice were noted in cardiac arrest (periprocedural and in-hospital), hospice disposition, or Society of Thoracic Surgeons Predicted Risk of Mortality risk score. A few (12%) programs maintained DNR status, thereby recognizing TAVR as palliative. Routine practices for documenting code status at discharge were not well-described. A multisociety expert decision clinical pathway is needed to address how TAVR can be life-prolonging, palliative or both. Patient-oriented processes related to goal-concordant surgical care are easing tensions addressing prior scrutiny of 30-day outcomes.[70,71] Geriatrics and palliative medicine can provide vital input to multidisciplinary Heart Teams responsible for reviewing TAVR candidacy and can help implement a proposed standardization of TAVR periprocedural approach to code status.[72]

ADVANCED CARE PLANNING IN THE CONTEXT OF TAVR.

Through careful communication, clinicians can gain insight into how TAVR fits into a patient's goals of care and priorities. Whether patients should proceed to TAVR as 'DNR' may depend on their specific circumstances, various preferences, and underlying motivation. Serious illness communication involves the following: 1) assessing how much the patient knows and wants to know about the illness and prognosis; 2) sharing information according to the patient's preferences and respond empathically to emotion; 3) exploring the patient's goals, values, and priorities with open-ended questions; and 4) making a medical recommendation about next steps for care, when indicated.[73] Increased proportion of family speech during family meetings has been associated with increased satisfaction with clinician communication and decreased ratings of conflict.[74]

The "heard and understood" metric is a new, valid, and reliable measure that could be adapted for patients and their care partners considering TAVR. It solicits the following from patients: 1) I felt heard and understood by this clinician and team; 2) I felt this clinician and team put my best interests first when making recommendations about my care; 3) I felt this clinician and team saw me as a person, not just someone with a medical problem; and 4) I felt this clinician and team understood what is important to me in my life.[75] Clinicians optimally guide decision-making based on patients' understanding of their illness in the context of their priorities, providing more personalized care along with emotional support.[76,77]

PROCEDURAL TECHNIQUES TO MINIMIZE RISK IN OLDER ADULTS

While a comprehensive discussion on optimal procedural techniques is available elsewhere,[49] procedural techniques can significantly minimize the risks of older patients with multiple chronic diseases and high burden of geriatric conditions (Table 3).

HEALTH TRAJECTORY POST-TAVR

Baseline functional status is an important evaluation that helps in risk stratification of older adults being considered for TAVR. However, the cardiovascular team may underestimate the potential longitudinal functional trajectory based on baseline assessment of functional status after TAVR. Kim et al carefully studied baseline and 1-year functional trajectory of patients who had undergone TAVR and outlined 5 health trajectories (excellent, good, fair, poor, very poor) based on a functional composite score determined by the number of activities of daily livings, instrumental activities of daily livings, and higher-functioning disabilities completed without assistance.[11] The health trajectory in this cohort could be characterized to have a square root shape (√) with a postprocedure initial decline in function and a subsequent attempt to a return to baseline. Overall, approximately 25% had functional decline, 33% improved, and the remainder maintained their pre-TAVR functional status. However, it is important to note that those with more favorable post-TAVR trajectories had higher baseline functional status while those with less favorable trajectories had lower baseline functional status.[78] Moreover, post-TAVR rehabilitation showed potential of improving markers of frailty such as gait speed at 1-year.[79]

POST-TAVR DELIRIUM

Delirium is from Latin—delirare—meaning ‘to go out of the furrow,’ deviate from a straight line, to be deranged. It is a severe neuropsychiatric syndrome that every cardiovascular team member should be aware of in regards to diagnosis and management. No randomized controlled trials (RCTs) have been conducted with delirium as a primary outcome and therefore incidence rates are found from observational studies.[80,81] Substantial heterogeneity has been reported with a 14% to 24% prevalence in older adults hospitalized in a general medical setting, and 8 to 20% after coronary artery bypass grafting surgery.[80] After TAVR, meta-analyses have reported the post TAVR prevalence of delirium is 24.9%.[82] There are 3 types of clinical presentations with delirium. The most common and worst prognosis is hypoactive delirium occurring in about 65% of patients, with hyperactive (symptoms of agitation) present in about 25% and mixed type found in about 10% of cases.[81] Delirium typically lasts for a few days to weeks, but in up to 20% of patients can last for months. Describing and identifying delirium as what it is and avoiding terminology such as acute brain failure/confusional state will help to further expand on our understanding of this complicated illness.[83]

Delirium diagnostic criteria and assessment depend on features of a fluctuating mental status, inattention, disorganized thinking, and changes in the level of consciousness.[80] The hallmark of delirium is disturbance in attention. Based on etiological contributors, the mechanism could be a single insult such as sedation-related delirium or multiple mechanisms with a trigger and an underlying substrate. Risk factors for delirium include baseline factors (advanced age, cognitive impairment, frailty, high comorbidity burden), factors relating to presenting condition (surgical stress, illness severity, infection, dehydration, difficulties with noninvasive ventilation), postadmission factors (pain, immobility, metabolic abnormalities, intensive care unit stay), and postoperative factors (sedation, sleep deprivation, constipation, urinary retention, and medications, invasive devices, prolonged ventilation).

Optimal management of delirium involves a multifaceted strategy as single therapies have not shown success, with particular attention to prevention. While pharmacological therapies are often used for hyperactive delirium, these medications should be used only when there is danger to self or others. Delirium must be distinguished from dementia, depression, and acute psychosis, and consultation with geriatrics, hospital medicine, or psychiatry may facilitate correct diagnosis. It is critical for the cardiovascular team to appreciate that potential mid-and long-term consequences of delirium include major neurocognitive impairment (dementia), physical and cognitive disability, depression, and post-traumatic stress disorder that may contribute to a poor quality of life.[84] Moreover, the inter-relationship between delirium and physical function was demonstrated in a recent study that showed the risk of delirium increased with lower physical function assessed by short physical performance battery scores.[85]

CARDIAC REHABILITATION AND PREHABILITATION

RATIONALE AND PURPOSE.

Replacement of an aortic valve only addresses part of the clinical challenges relevant for typical older TAVR patients. Most TAVR patients also endured functional decline, with associated frailty, sarcopenia, and disability with the temporal progress of the AS. Thus, even when the stenotic aortic valve is successfully replaced, it is not easy to overcome the functional losses as they are often quite entrenched. Prognostic implications are significant. In a study of 912 TAVR patients, Lindman et al noted that only 39% of patients had a clinically meaningful improvement (≥0.10 m/s) in gait speed 1 year after TAVR.[79] No change (±0.10 m/s) was noted in 35% of the patients, and a clinically significant decline was observed in 26% of patients. There was a 3.5-fold increase in death/hospitalization between 1 and 2 years for patients with a slow gait speed (defined as <0.83 m/s) at 1 year, compared to patients with gait speed ≥0.83 m/s.[79] In contrast, patients whose slow gait speed normalized at 1 year had no increased risk. Quality of life at 1 year was also better in association with faster gait speed (þ1.95 Kansas City Cardiomyopathy Question points per increase of 0.1 m/s in gait speed; 95% CI: 1.32–2.56; $P < 0.001$). Echocardiographic parameters were not associated with gait speed. A key implication is that cardiac rehabilitation (CR) stands out as a therapeutic approach that is complementary to valve replacement, with the potential to improve vital physical function and overall prognosis.

CR is a multidisciplinary secondary prevention program designed for patients after a cardiovascular event (eg, myocardial infarction, percutaneous or surgical revascularization, and other cardiac surgical procedures) to promote acute recovery and long-term cardiovascular health through exercise training, cardiac risk factor management, lifestyle modification, social support, and education. In CR, exercise is prescribed and supervised, providing opportunities to formulate and administer a progressive exercise regimen that includes resistance and balance training in addition to aerobic modalities. Resistance training is a critical component for TAVR patients. This form of exercise has the potential to allay sarcopenia and restore key aspects of function that are especially important for a population that is especially prone to sarcopenia and frailty as valve stenosis progresses over time.[86]

CR provides an opportunity to implement nutritional support, including options for protein enriched diets that have been demonstrated to reduce sarcopenia.[55] Similarly, the surveillance provided through CR is especially advantageous for post-TAVR patients whose hearts typically undergo postprocedure remodeling and associated fluctuations in hemodynamics. CR provides opportunities to adjust medication dose and even consider deprescription if medications (eg, beta blockers) no longer provide clinical value.[42] CR also provides social opportunities that are valued by many TAVR patients, especially as many endure isolation associated with the sedentariness, fear, and symptoms (eg, angina, dyspnea) in the months/years prior to their TAVRs.

CURRENT EVIDENCE OF UTILITY FOR CR IN TAVR PATIENTS.

Studies of on-site CR programs have been predominantly small but suggest overall benefit for patients post-TAVR, with improved functional capacity, exercise tolerance, and health-related quality of life.[87,88] A meta-analysis comparing the safety and outcomes of CR in 292 patients post-TAVR and 570 patients post-SAVR revealed that CR (including resistance, endurance, and/or respiratory muscle training) was safe and that both 6-minute walking distance and functional independence (Barthel Index) improved (in both TAVR and SAVR patients).[89] Pressler et al conducted a pilot RCT in 30 patients (mean age 81 ± 6 years, 44% female) comparing CR vs usual care post TAVR, showing that CR was associated with relative improvements in peak VO_2, muscle strength, quality of life, and symptom burden.[90]

Nonetheless, logistic barriers often limit options for CR participation, especially as many TAVRs are performed in tertiary centers that can be far from the patient's home. Several trials have explored the utility of remote-based models for CR in older post-TAVR patients. While remote-based approaches for CR post-TAVR are conceptually compelling, the challenges of managing frailty, sarcopenia, and other risks in the older TAVR population using remote formats are difficult, and studies have not yet demonstrated a clear signal of feasibility or benefit.[79,91] A recently launched multicenter home-based CR trial (R01 AG073633) using a novel mobile health exercise regimen following transcatheter heart valve interventions (HOME RUN HITTER) is exploring these issues more definitively.

TECHNOLOGY IN THE CARE OF OLDER TAVR PATIENTS

Gerotechnology is any digital health technology that aims to lower treatment risk, improve quality of life, and alleviate symptoms in older adults with or at risk of medical or surgical illness. It also aims to introduce and distribute health technologies in an equitable fashion tailored towards older adults. Moreover, it specifically encompasses a layer of geriatric-sensitivity during the development and operational phases to improve patient-centered care.[92] In the context of this review, automated electronic frailty indices have been developed that can be integrated into the electronic health records to capture existing data to calculate a frailty index.[29,60,61] eFIs are excellent screening tools that correlate with in-person frailty assessments. Where data are available, a semiautomated version of the

CGA-FI can similarly be integrated. Elements of the CGA-FI that require manual input can be done by members of the multidisciplinary heart team.

The incremental addition of artificial intelligence, in addition to the adoption of CGA-FI or other eFI data into the electronic health records, has potential applications such as risk stratification, image analysis, surgical planning, possible real time procedural guidance, postoperative monitoring, predictive analytics, and the possibility of personalized recommendations. Artificial intelligence powered sensors and cameras can be used for example to detect an older adult's gait and balance. By analyzing movements in real-time AI can identify potential fall risks and respond to this by trigger alerts and possible intervention. Similarly, AI-powered home automation can make living spaces more accessible for older adults. While AI is rapidly growing in older adult care, applications are not currently available for patients specifically with AS or the post-TAVR time-period. However, the potential power of AI should spark increased research in this area.

GAPS IN KNOWLEDGE AND LIMITATIONS.

Several knowledge gaps exist in the management of older patients with severe symptomatic AS and these gaps involve multiple stakeholders including the patients themselves, their caregivers, health care professionals, and community members. Table 4 lists gaps in knowledge and future directions to optimize care for older adults with severe AS considered for TAVR. Our review is based on current data available in the field of geriatric cardiology as it applies to patients with severe AS being considered for TAVR. We acknowledge the varying levels of evidence and the paucity of RCTs that provide a sufficient depth or breadth of geriatric conditions.

CONCLUSIONS

Severe symptomatic AS can and should be considered a model for geriatric cardiovascular conditions because it has urged the cardiovascular community to realize the limitations of chronological age when assessing older adults with multiple geriatric conditions. Closely following the technological evolution of transcatheter heart valves has been an appreciation of the necessity of incorporating geriatric conditions. While frailty is 1 component of the geriatric assessment it is time to routinely incorporate a more comprehensive geriatric assessment into the assessment of complex older cardiovascular patients. Evidence to support the role of the CGA in cardiovascular disease is evolving. Online tools such as the CGA-FI that can be incorporated into electronic health records will most certainly enable cardiology as a specialty to routinely integrate geriatric precepts into the care of older patients. The incremental layering of artificial intelligence, if gerotechnology principles are incorporated, should lead to a more patient-centered focus of care. The cardiovascular community, through the routine application of geriatric precepts, is on the precipice of an opportunity to improve quality of life for the current cohort of older adults with cardiovascular diseases, and the prospects for future cohorts are extremely bright as clinical and technological advances in care continue to evolve.

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ABBREVIATIONS AND ACRONYMS

AS	aortic stenosis
CGA	comprehensive geriatric assessment
CMR	cardiac magnetic resonance
CR	cardiac rehabilitation
CT	computed tomography
FI	frailty index
HF	heart failure
LV	left ventricle
LVEF	left ventricular ejection fraction
RCT	randomized controlled trial
SAVR	surgical aortic valve replacement
SMART	Specific, Measurable, Achievable, Relevant and Time-Limited
TAVR	transcatheter aortic valve replacement

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PERSPECTIVES

- Calcific aortic stenosis serves as a model for geriatric cardiovascular conditions because it is prevalent among older patients living with geriatric syndromes.
- Given the complexity of the aging process, stratification by chronological age should be only the initial step in TAVR evaluation, as it is insufficient sufficient to optimally quantify both cardiovascular and noncardiovascular risk.
- The CGA-FI should be integrated into the pre-TAVR workup for assessing geriatric risks because of its ability to comprehensively assess physical and cognitive functions and predict post procedural outcomes via a multidisciplinary approach.

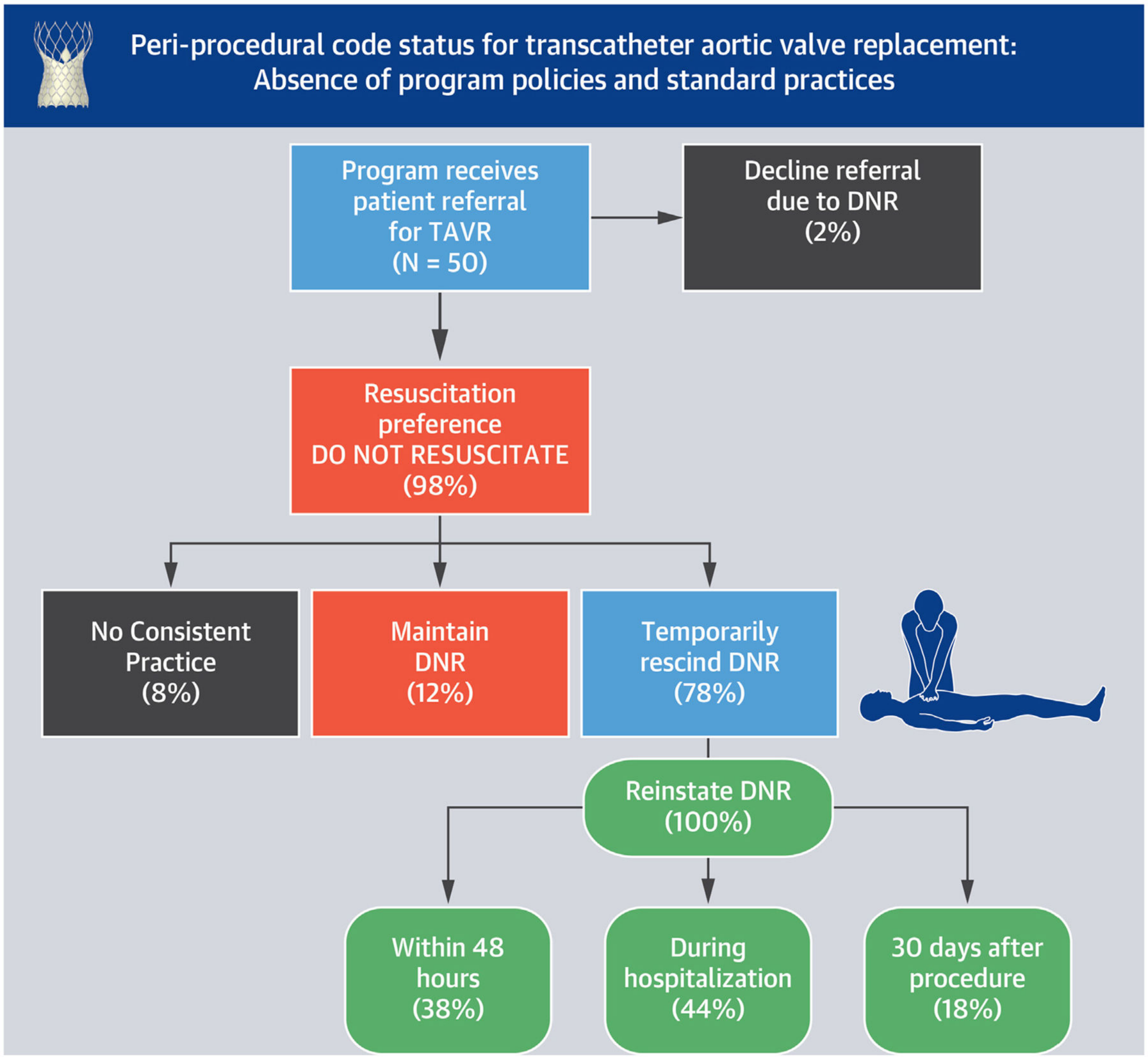
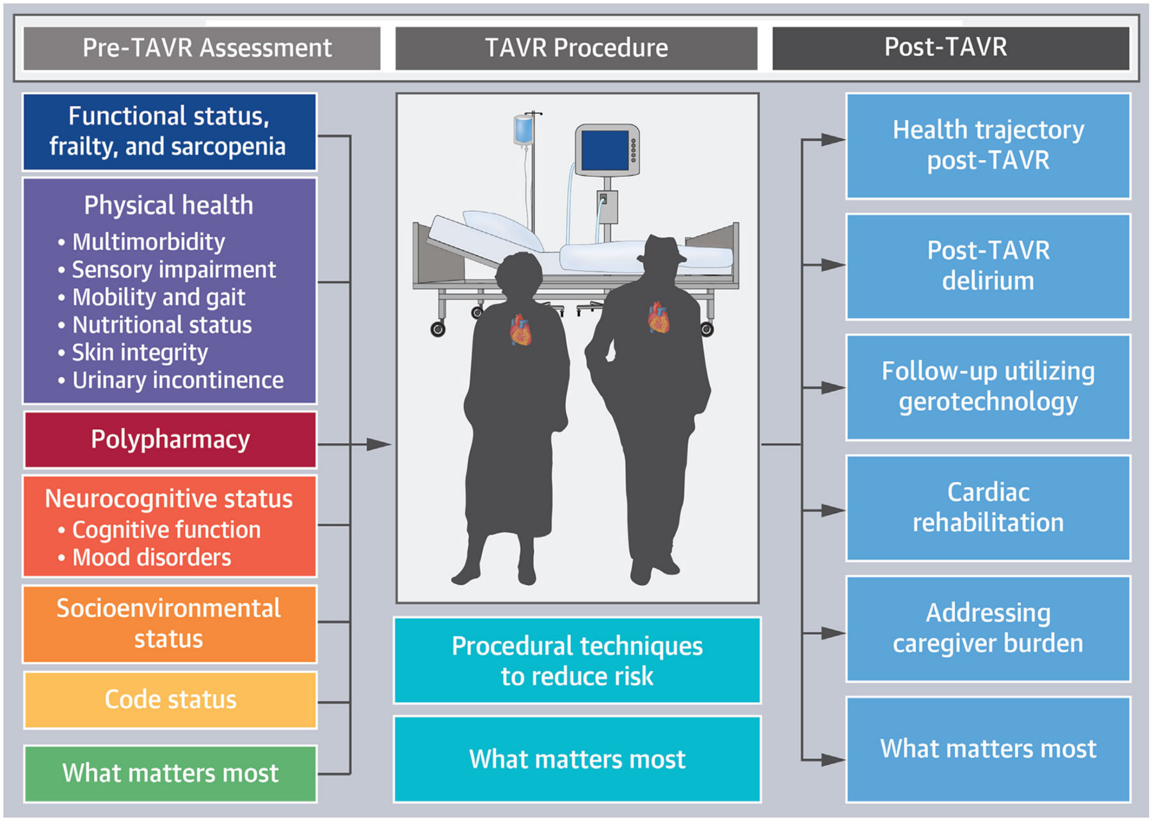


FIGURE 1.

Periprocedural Code Status Practices in TAVR Programs in Washington and California

Revised from Bernacki et al.[69] TAVR = transcatheter aortic valve replacement.



CENTRAL ILLUSTRATION.

The Complexity of TAVR in Older Adults With Aortic Stenosis: Moving Towards a Comprehensive Geriatric Assessment and Away from Chronological Age

Comprehensive geriatric assessment along with physical frailty for older adults in (left) pre-, (middle) during, (right) post-transcatheter aortic valve replacement procedure. Addressing age-associated risks lowers the morbidity and mortality implications of falls, sarcopenia, cognitive and physical dysfunction, malnutrition, and other geriatric conditions. “What Matters Most” to older patients reflects the critical health care decisions related to the transcatheter aortic valve replacement procedure that could drive customized treatment plan to sustain and improve health at old age. Knowing and aligning care with each older patient’s priorities, values, and preferences reflects a better approach to invasive cardiovascular care and structural heart procedures. TAVR = transcatheter aortic valve replacement.

TABLE 1

Tips on How to Evaluate and Manage Delirium Post TAVR

Stage	Action
Assessment	• Assess the risk factors for delirium pre- and post-TAVR, especially those aged ≥75 y, those with cognitive impairment and frailty. • Assess uncontrolled pain, drugs, electrolytes, lack of drugs, infections, dehydration, reduced sensorial input, sleep deprivation, and other neurologic or cardiopulmonary disorders.
Prevention	• Prevent delirium by addressing complications post-TAVR. • Use tailored multicomponent intervention (eg, Hospital Elder Life Program).
Screening	• Screen for incident delirium by using a validated screening tool (eg, UB-2[50]) post TAVR procedure.
Diagnosis	• Diagnose delirium using a validated tools (eg, 3D-CAM[51]) conducted by a trained health care professional.
Management	• Maintain patient comfort and safety. • Manage delirium by identifying and managing possible causes, ensuring effective communication and reorientation and providing reassurance. • Involve family, friends, and caregivers providing care for engagement.
Management of severe agitation that threatens the safety of the patient or others	• Use verbal and nonverbal deescalation techniques. • If these measures are not effective, consider short-term, low-dose antipsychotic (eg, haloperidol or atypical antipsychotics); titrate according to symptoms; monitor QT interval, and reassess the need for continued use. • Avoid using antipsychotic drugs if possible, in patients with Parkinson disease or Lewy body dementia.

TAVR = transcatheter aortic valve replacement.

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TABLE 2

Examples of Patient-Centric Outcomes and Proposed Study Methods for Future Research and Clinical Practice

Examples of patient-centric quantitative measure	
• Time at home. • Improved perceived health. • Unwanted adverse effect from the procedure. • Obtaining psychological well being. • Satisfaction with the care. • Functional improvement.	These outcomes should be included as patient-centric outcomes in future clinical trials and prospective cohort studies Multiple domains of CGA should be assessed as both initial assessment and outcome
Examples of patient-centric qualitative measure	
• Patient's preferred goal using their own words, what they would like to achieve after TAVR.	Goals can be assessed using Patient Priorities Care model and qualitative analysis
Examples of outcome measurement from a societal perspective	
• Caregiver burden. • Economic outcome. • Cost-effectiveness analysis.	These outcomes reflect the effectiveness of TAVR from a broader perspective reflecting the nature of complex multidisciplinary care for older adults

CGA = comprehensive geriatric assessment; TAVR = transcatheter aortic valve replacement.

TABLE 3

Procedural Techniques to Minimize Risk for Older Adults Undergoing TAVR Procedures

Technique	Description	Benefit/Purpose
Use ultrasound and fluoroscopy for vascular access[44]	Combined with femoral angiography through micropuncture sheath prior to the insertion of large bore sheaths	Lowers vascular and bleeding complications, particularly for higher risk older patients.
Use a 21-gauge micropuncture needle[44]	Reduced the size of the initial puncture and associated extravasation of blood during sheath insertion and exchange.	Minimizes the risk of vascular complications
Use radial artery for secondary access[45]	For pressure monitoring, gradient determination, and root angiography	Lower vascular complications, mainly for patients with obesity, peripheral vascular disease, and hostile tortuous vascular anatomy.
Use balloon tipped temporary pacemaker[46,47]	For right ventricular pacing	Lowers risk of pericardial tamponade
Shaping the extra stiff 0.035-inch exchange length guide wire	Important for positioning in the left ventricular apex without causing perforation or undue ventricular arrhythmia	Reduced the risk of perforation and arrhythmia
Predilation and direct TAVR[48]	Predilatation for lower risk patients with critical aortic stenosis, but direct TAVR for high-risk older adults	Direct TAVR decreases procedural duration and is safe without predisposition for post dilation
Deployment of balloon-mounted valve vs self-expanding valve[49]	Balloon mounted at 180 to 200 beats/min, self-expanding at 120 beats/min	Reduces risk of valve embolization, reduced risk of myocardial ischemia in high-risk older patients
Use of suture-based devices and final angiographic images[44]	After valve deployment to achieve hemostasis and assess large bore vascular access by performing peripheral angiography	Minimizing risks of bleeding and vascular complications

TAVR = transcatheter aortic valve replacement.

TABLE 4

Gaps and Future Directions to Consider for Optimizing Care in Older Adults With Severe AS Being Considered for Transcatheter Aortic Valve Procedures

Problem	Problem Expansion	Proposed Solutions
Current datasets not leveraged for geriatric assessments		
Clinical presentation, imaging, biomarkers	Refinement of the original E. Braunwald's natural history of AS based on chest pain, syncope, and heart failure to incorporate a comprehensive geriatric assessment and the role of frailty.	Increase the use of existing large datasets for better understanding of contemporary natural history
	Improve imaging and biomarker studies by incorporating a comprehensive geriatric assessment	Link imaging and biomarker data with individual patient level data that includes geriatric conditions
Individual components of the comprehensive geriatric assessment	Individual components of the comprehensive geriatric assessment, such as dementia or sarcopenia, are often viewed as in a dichotomous manner. This often leads to the exclusion of adults with these conditions for cardiovascular procedures.	Routine incorporation of dementia or sarcopenia staging to optimally match treatment proposal with clinical status of patient.
Comprehensive geriatric assessment	The current method of obtaining a comprehensive geriatric assessment is time-consuming. Novel methods such as the comprehensive geriatric assessment-frailty index that have important components of the comprehensive geriatric assessment and frailty will need to be further studied and validated.	Consider incorporation of comprehensive geriatric assessment-frailty index into registries and clinical trials.
	There is a significant gap in knowledge regarding caregiver burden.	Studies can consider components of the comprehensive geriatric assessment or the comprehensive geriatric assessment-frailty index as a whole as an exposure variable, confounder, or outcome.
Enhancement of TAVR RCT reporting of geriatric conditions	Prior trials have emphasized on frailty, a component of a comprehensive geriatric assessment, rather than a full performance of the assessment.	Increasing awareness of the necessity of the comprehensive geriatric assessment.
	While randomization aims to optimize covariate balance, there is lack of mechanistic understanding of geriatric conditions.	Observational studies that explore mechanistic associations of geriatric conditions with outcomes.
Expansion of the MDHT	Current MDHT do not incorporate geriatricians, geriatric cardiologists, palliative care specialists, Physical Medicine & Rehabilitation clinicians, or other critical ancillary staff (physical/occupational therapy, social worker)	Incorporation of these members to the MDHT in varying capacities. Functional experts, in coordination with cardiovascular medicine expertise, can consider additional studies in the space of potential prehabilitation.
Paucity of cost and cost-effectiveness studies	Need for cost studies and cost-effectiveness studies that routinely incorporate geriatric condition variables	Increase reporting of cost-effectiveness analysis that account for geriatric conditions from RCTs and registry data.
Inefficient shared decision-making tools	Shared decision-making could be improved by better understanding of statistical variables such as restricted mean survival time, time to benefit, time to harm, number needed to treat that have incorporated geriatric conditions	Future studies should consider incorporating these variables in order for optimizing bedside discussions with patient/family.
Lack of sufficient patient-centered outcomes in RCTs	The current focus on major adverse cardiovascular events (while important) does not always allow for assessment of potential harm measured in a patient-centric manner	An assessment at baseline and at follow up of function (ADL, IADL, Nagi *Rosow-Breslau*) is critical as that can lead to a better understanding of health trajectory. Further novel functional tools need to be explored.
Under representation of older adults in RCTs	Substantial under representation in RCTs of older adults, women, and minority populations.	

ADL = activities of daily living; AS = aaortic sstenosis; IADL = instrumental activities of daily living; MDHT = multidisciplinary heart team; RCT = randomized clinical trial.