Review

A Practical Approach to Managing Transcatheter Aortic Valve Replacement With Sedation

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Abstract

Transcatheter aortic valve replacement is increasingly performed as a minimally invasive treatment option for aortic valve disease. The typical anesthetic management for this procedure was traditionally similar to surgical aortic valve replacement and involved general anesthesia and transesophageal echocardiography. In this review, we discuss the technological advances in transcatheter valve systems that have improved outcomes and allow for use of sedation instead of general anesthesia. We describe an anesthetic protocol that avoids general anesthesia and utilizes transthoracic echocardiography for procedural guidance.

Keywords

transcatheter aortic valve replacement, monitored anesthesia care, transthoracic echocardiography, aortic valve replacement, minimally invasive surgery

Introduction

Transcatheter aortic valve replacement (TAVR) has become a safe alternative to surgical aortic valve replacement (SAVR) in high-risk patients.[1] Once reserved exclusively for a specific population with inoperable aortic stenosis, popularity has increased as selection criteria has expanded,[2,3] now including patients with aortic insufficiency,[4,5] bioprosthetic aortic valve disease,[6] and lower surgical risk.[7] The combination of greater experience, fewer patient comorbidities, and improved device technology has allowed for a less invasive anesthetic technique, which avoids general anesthesia (GA) and tracheal intubation. While there have been no prospective randomized trials, sedation for TAVR was shown to have similar complication rates compared with GA in a review of more than 2300 patients enrolled in the multicenter FRANCE 2 registry.[8] These results have been confirmed by smaller observational studies that have additionally shown an association with greater hemodynamic stability intraoperatively and less adrenergic support,[9-11] decreased procedural time,[9,12-15] decreased hospital[12-16] and intensive care unit (ICU) length of stay,[15,16] with no change in short-term[12,15] or midterm survival.[13,16] In this review, we discuss the technological and imaging advances that have facilitated the avoidance of GA and describe a technique that utilizes regional anesthesia, sedation, transthoracic echocardiography (TTE),

and may facilitate early ambulation and enhanced recovery after TAVR via the transfemoral (TF) approach. Our surgeon has performed approximately 2000 TAVR to date, and our anesthesia team has performed more than 200 cases under sedation in the past year.

Next-Generation Technology

In 2002, Cribier and colleagues performed the first human TAVR as a "last resort" via a 24-French femoral venous sheath and a transseptal, anterograde approach.[17] The valve was positioned using fluoroscopy and confirmed after deployment with transesophageal echocardiography (TEE) within 30 minutes. The patient improved hemodynamically but ultimately succumbed to noncardiac complications after 17 weeks. Despite the complexity of the procedure, it was performed under sedation.

In following years there was a greater reliance on TEE for evaluation and confirmation of proper positioning.[18,19] GA was almost universally used in these patients due to

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concern for airway obstruction with long procedural time, but also because of an elevated risk of hemodynamic instability and vascular injury due to system size. A 2009 review of anesthetic considerations for TAVR describes a GA technique similar to SAVR except that medications were titrated to allow tracheal extubation at the end of the procedure, when possible.[20] The authors described their initial experience involving a population with a predicted operative mortality risk of greater than 15% and utilizing a 24- or 26-French deployment system. Of patients undergoing TF TAVR, 52% required blood products during the procedure, with a median procedural time of 5.5 hours.

With improvements in device size and additional experience, TAVR with sedation was becoming more widespread in Europe, where transcatheter valves were approved for use 4 years before the United States.[2,12] In 2007, Grube et al reported results comparing TF TAVR using a second-generation, 21-French system to the third-generation, 18-French system.[10] Their results showed the smaller device required significantly less procedural time and cardiovascular support. They reported 25% of their 18-French systems were placed with local anesthesia and sedation, compared with 0% of the 21-French systems. Data from the European TransCatheter Valve Treatment Sentinel Pilot Registry (TCVT) showed that by 2011-2012, countries with extensive experience with TAVR such as Switzerland were performing 84% of cases under sedation.[12] Other sources estimated the sedation rate in Europe to be above 50% in 2011.[21] In contrast, a February 2012 survey of 62 North American centers involved in TAVR clinical trials revealed that only 5% routinely used sedation.[22] According to the STS/ACC TVT Registry™, in 2014 only 5.0% of commercial TAVR procedures submitted to the registry were performed with sedation.

Currently in the United States, the Medtronic CoreValve (Medtronic, Minneapolis, MN) and Edwards SAPIEN (Edwards Lifesciences LLC, Irvine, CA) are the 2 TAVR systems approved for use by the US Food and Drug Administration (FDA). Both have undergone several changes since their initial approval. These modifications have greatly helped facilitate the transition of this procedure from routine GA to sedation.

The CoreValve platform is a self-expanding nitinol frame with leaflets made of porcine pericardium. The newest version is the Evolut-R, and was FDA approved in June 2015. It is available in 3 sizes (23, 26, and 29 mm). This system has been modified so the device is now repositionable and retrievable such that if the valve is placed in a suboptimal position it can easily be relocated even after near complete deployment. The system has also been created with an inline sheath that makes the device the equivalent of a 14-French sheath, currently the smallest caliber device on the market. Other modifications have included a change in the inflow of the stent to both optimize a seal and lessen paravalvular aortic regurgitation (PAR). It has also been modified to reduce the risk of conduction disturbances (CD). An 18-French, 31-mm CoreValve system is also available from the previous generation.

The SAPIEN platform is a balloon-expandable system consisting of a cobalt-chromium frame and bovine pericardial leaflets. The newest version of this line is the SAPIEN 3 system, also FDA approved in June 2015. The primary modification has been the addition of a skirt at the inflow to lessen the rate of PAR. The device has also been made smaller and fits into a 14- or 16-French eSheath. The eSheath is an expandable introducer sheath system that utilizes a dynamic mechanism that requires expansion beyond the initial 14- or 16-French size to permit passage of the valve. This system comes with 4 valve sizes (20, 23, 26, and 29 mm).

It is important to note that the sizing for these systems is not interchangeable, as a self-expanding system requires more oversizing. For example, a patient that requires a 23-mm balloon-expandable (SAPIEN) device may require a 26-mm self-expanding (CoreValve) device. Both of these systems are now sized predominately and preferentially by preoperative gated computed tomography angiography (CTA) and thus have reduced the need for intraoperative sizing.[23] The deployment of these systems is also quite different. The balloon-expandable systems require rapid pacing during deployment to facilitate a period of cardiac standstill to prevent migration while the balloon is inflated. This is not required with the self-expandable systems; however, there is a period of relative hypotension when the inflow of the valve has engaged the annulus but the commissures on the outflow have not yet opened. With both valves the period of hypotension is usually under 60 seconds.

Management of Patients Undergoing TAVR With Sedation

Presurgical Assessment

Patients considered for TAVR require a comprehensive workup from a formal heart team, which includes a cardiologist and cardiac surgeon. The patient must be considered to be high risk for traditional surgery with a high-predicted mortality or major morbidity. This is primarily based on major comorbidities included in the STS Risk Calculator, but may also be due to specific anatomic characteristics such as mediastinal adhesions after a previous sternotomy. The anesthesiologist should review this workup prior to the day of surgery including routine blood tests, electrocardiogram, chest x-ray, TEE or TTE, and cardiac catheterization results. Additional information about the procedure including type of valve, access location, and any concurrent procedures should be known.

Table 1. Contraindications to TAVR With Sedation.

Airway
  History of difficult intubation
  Suspected difficult intubation on exam
  Severe obstructive sleep apnea
  High risk of aspiration, including severe GERD or full
    stomach
Inability to tolerate supine position
  Severe musculoskeletal disease or back pain
  Congestive heart failure with severe orthopnea
Patient cooperation
  Patient preference of GA
  Barriers to communication including language barriers, or
    dementia
Surgical considerations
  Transapical, subclavian, or direct aortic approach
  Extensive TEE requirements
  Concurrent surgical procedures

Abbreviations: TAVR, transcatheter aortic valve replacement;
GERD, gastroesophageal reflux disease; GA, general anesthesia; TEE,
transesophageal echocardiography.

Patients undergoing TF TAVR either via percutaneous or direct arterial cut down approach are candidates for sedation with an ilioinguinal and iliohypogastric nerve block. When properly performed, injection of local anesthesia should adequately anesthetize the insertion site. The primary purpose of sedation is to facilitate patient comfort while remaining motionless during the procedure. A truly informed consent and careful explanation of the anesthetic technique is imperative, as cooperation is required and the patient does not move during the procedure. We typically describe the anesthetic to be similar to a cardiac catheterization, which nearly all our TAVR candidates have experienced. The final anesthetic plan is determined and consent is obtained on the day of surgery after physical examination.

Contraindications to Sedation

Anesthetic contraindications to sedation for TAVR are similar to those for other surgical procedures (Table 1). In general, they include airway concerns, patient refusal, and anything that may prevent the patient from being positioned supine while remaining motionless for 2 hours or more. The critical role of the anesthesiologist preoperatively is to determine whether contraindications are absolute or relative. A thorough history and examination will determine the severity of impairment to sedation and whether conditions can be optimized to allow for this technique.

Patients who have a known history or are suspected to be difficult to intubate should be strongly considered for GA, as emergent intubation may be required during the procedure. Common causes of difficult intubation in patients presenting for TAVR include obesity, limited neck extension, or limited mouth opening, as well as previous pharyngeal or laryngeal surgery or radiation. Poor mucosal integrity may make this population prone to oropharyngeal swelling and bleeding, which could impair visibility should multiple attempts at laryngoscopy be required. This is especially true given that all patients receive antiplatelet therapy the morning of their procedure.

Individuals who are prone to obstruction with sedation should also be considered GA. Screening tools for obstructive sleep apnea, including the STOP-BANG score may be helpful in determining who is at risk for severe disease.[24] Severe gastroesophageal reflux disease or significant pulmonary secretions are also a relative contraindication to sedation, particularly in those with worse symptoms while supine or a history of recurrent aspiration pneumonia. Patients who do not meet fasting guidelines or who are otherwise high risk for aspiration should not be given sedation for TAVR.[25]

Some contraindications to sedation are more subjective and require careful attention. TAVR candidates with advanced age may have spinal deformities or other musculoskeletal disease causing lower back pain. Patients with severe congestive heart failure may report worsening symptoms of dyspnea when supine, particularly when not medically optimized for surgery. Our practice is to allow patients position themselves to ensure comfort before administering any sedation. This may include positioning a pillow under the patient's knees and additional head support to facilitate flexion of the hip and neck. This usually permits acceptable surgical conditions as long as the hip is flexed at an angle of less than 30°. Patients who do not speak English or those with other barriers to communication such as severe dementia may be difficult to manage should they become anxious or begin to move excessively. Furthermore, inability to communicate may negate a key benefit to sedation, namely, the early discovery of complications including acute neurological deficits, myocardial infarction, new-onset heart failure, and aortic dissection.

There may be surgical contraindications to sedation for TAVR. Transapical, subclavian, carotid, or direct aortic approaches are not generally considered candidates for sedation at our institution. TTE imaging windows are likely to be impeded in these locations, effectively necessitating TEE. TAVR has been performed via the transapical approach under thoracic epidural anesthesia.[26] The combination GA and either thoracic epidural or single injection paravertebral blockade has also been described.[27,28] Concern for spinal epidural hematoma has limited the use of neuraxial techniques in patients that receive aspirin and clopidogrel preoperatively.[29]

Patients with severe renal disease who have not undergone CTA with intravenous contrast might require additional workup. This may include TEE, which may be more accurate than TTE in assessment of aortic annulus diameter.[30] The use of TEE does not absolutely preclude the use of sedation for TAVR. Data from TCVT showed that 10.9% of sedation cases received a TEE evaluation.[12] One institution reported using a minimally invasive nasopharyngeal TEE probe before changing practice to incorporate TTE.[13] However, the use of TEE during sedation for TAVR may require a greater amount of sedation that predisposes to worsening obstruction or hypoventilation. Our current preference is to facilitate a "quick look" with a smaller pediatric probe under sedation when needed but not to routinely perform TEE for extended periods when not clinical necessary.

Intraoperative Considerations

There is limited uniformity in the literature regarding how local anesthesia is administered for TAVR. Our practice is to perform bilateral ilioinguinal and iliohypogastric nerve blocks, as described by other institutions.[13,31] In our experience, local anesthetic skin infiltration alone may not suffice and increases intravenous sedation requirements.

The ilioinguinal nerve courses anteriorly and inferiorly to the superficial inguinal ring and innervates the skin on the superior and medial portions of the thigh. The iliohypogastric nerve innervates the skin at the inguinal crease.[32] Our technique involves inserting a 22-gauge blunt tip needle perpendicular to the skin, 2 cm superior and 2 cm medial to the anterior superior iliac spine. Loss of resistance is felt as the needle passes the external oblique muscle, and 2 mL of 2% lidocaine is injected. The needle is again advanced until a loss of resistance is again appreciated as it passes the internal oblique muscle and 2 mL of 2% lidocaine is injected. The technique is repeated with the needle 45° medial, and then 45° lateral, for a total of 12 mL local anesthesia, or 24 mL bilaterally. With a proper block, many patients report the TTE examination to be the most uncomfortable part of the procedure, particularly the subcostal 4-chamber view.

Intravenous sedation for TAVR has been previously reported using propofol,[13-16] ketamine,[14] midazolam,[9,11] dexmetedomidine,[14] and remifentanil,[11,13,15,31,33] alone or in combination with other agents. TAVR has also been performed under solely local anesthesia without sedation.[16] We have used each of these regiments and recommend dexmedetomidine 0.4 to 0.9 µg/kg/h with the addition of low-dose propofol (20-50 µg/kg/min) as a second agent if necessary. A bolus of 30 mg propofol may be used to facilitate urinary catheter placement. Narcotics including fentanyl and remifentanil are generally not necessary with ilioinguinal and iliohypogastric blockade. It should be emphasized that sedation should primarily be thought of as allowing the patient to remain supine and motionless for the duration of the procedure. Perhaps counterintuitively, we turn off any intravenous sedation just before deployment. We find this allows for a complete neurological assessment within minutes of valve implantation. We initially expected that valve expansion would be particularly stimulating, or that the proceduralist would require absolute motionless during this critical time in the case. With experience we have found this is not the case. Instead, we find the most important time for the patient to remain motionless is during placement of the large femoral arterial sheath, when surgical stimulation may increase the risk of vascular injury.

Minimal or no hemodynamic support is usually required with sedation. Radial artery cannulation is performed for continuous blood pressure monitoring. Intraoperative CVP is not routinely monitored. Norepinephrine at 0.02 to 0.08 µg/kg/min is our preferred vasoactive infusion when necessary, and we find minimal or no increase in heart rate at clinical doses. Brief hypotension that occurs during placement of either self-expanding or balloon-expandable systems should be pretreated with the norepinephrine infusion or with a 1 unit bolus of vasopressin to maintain an initial systolic blood pressure above 130 mm Hg before proceeding, similar to previous reports.[13] Systemic delivery of medications is impaired during this period of low cardiac output and rebound hypertension can occur if vasopressors are given in excess during deployment.

Transvenous Pacing Wire Placement

Transvenous pacing (TVP) at a high frequency is a technique utilized to temporarily reduce aortic pressure and pulsatility, facilitating deployment of balloon-expandable systems. It may also be used for balloon aortic valvuloplasty, which may be performed before or after deployment of both balloon-expandable and self-expanding systems. Intraoperative TVP capability is thus established in all cases prior to the procedure.

Postoperative pacing may also be required due to temporary or permanent CD related to valve deployment. This has been reported to occur most frequently in self-expanding valve systems that may cause compression of the left bundle branch within the left ventricular outflow tract.[34] A CD is usually diagnosed within 48 hours of implantation, is often transient in nature, and thought to be due to temporary inflammation caused by mechanical trauma.[35] Permanent pacemaker implantation (PPI) has been reported in 10% to 47% of patients following implantation of self-expanding valves.[36-40] The optimal position of this valve extends ≤6 mm below the aortic annulus, and deeper implants have been associated with a higher incidence of CD and PPI.[41] In comparison, PPI is observed in 3.9% to
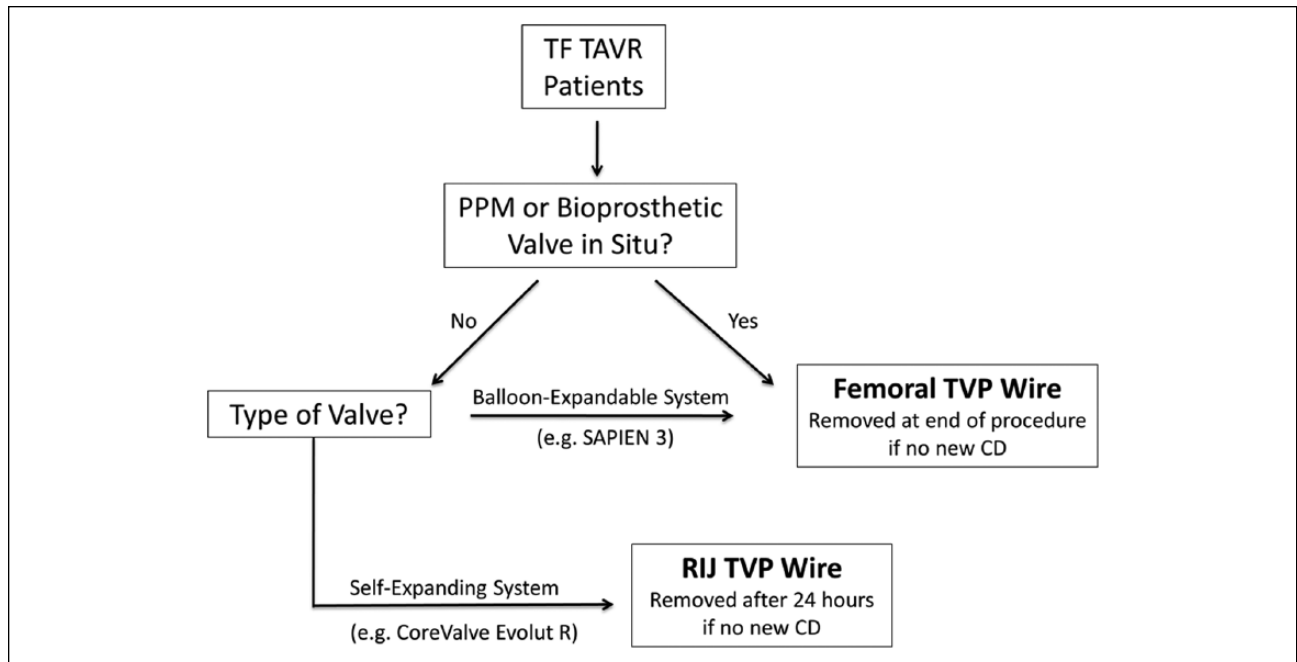
Figure 1. Algorithm for determining site of transvenous pacing wire placement.

11.0% with balloon expanding systems.[38,42,43] As a result, our practice is to provide TVP capability for at least 24 hours with self-expanding devices, and only in patients with new-onset CD receiving balloon expanding devices.

In addition, patients with previous PPI will not require postoperative TVP, and those who have undergone previous TAVR or SAVR are thought to be less likely to develop CD. It is hypothesized that the conduction system within the outflow track is protected by the bioprosthesis. Results from the Global Valve In Valve Registry showed PPI was required in only 8.9% of patients undergoing CoreValve procedures.[44]

The preferred site for TVP varies based on the type of valve and surgical history (Figure 1). Our primary preference is to avoid femoral sheaths in the postoperative period, as this precludes early mobilization and may contribute to pulmonary complications as well as prolonged ICU and hospital length of stay.[45] Pacing via the right internal jugular vein (RIJ) is used in patients who will require postoperative TVP capabilities. However in those at low risk for CD, we prefer the placement of a femoral pacing wire prior to the procedure and removal before leaving the operating room. The RIJ is smaller in spontaneously breathing patients compared with patients receiving positive pressure mechanical ventilation, and Trendelenburg position for placement may be poorly tolerated in this population. Compared with femoral cannulation, RIJ access may be more difficult to achieve with patient movement. These factors make RIJ cannulation more time consuming and with greater potential for

serious complication including carotid puncture. In our experience, TVP via the femoral vein can be established by the proceduralist efficiently while obtaining femoral artery access, and without the need for a separate sterile prep and draping of the patient. Regardless of location, TVP is achieved by placing an 8-French sheath with a locking mechanism. A 5-French balloon tipped pacing wire is then advanced into the RV under fluoroscopic guidance. Appropriate capture threshold (typically 1 mA) is confirmed. The anesthesiologist should always be provided central venous access for rapid administration of volume and vasoactive agents if necessary.

Intraoperative Complications

Despite improvements in device technology and surgical experience, complications remain a concern. While equipment to convert to GA must always be readily available, it is often not necessary and in some cases potentially harmful. In our experience, sedated patients routinely maintain spontaneous ventilation during transient induced hypotension from valve deployment for periods of 60 seconds or more. Induction and positive pressure ventilation may not be optimal management in a hypotensive patient. Our preferred treatment of intraoperative pericardial tamponade involves local anesthesia and a subxiphoid needle decompression and pericardial drain placement with maintenance of spontaneous ventilation when possible. Repair of vascular injury including temporary iliac artery balloon occlusion and simple open vascular repairs may be tolerated

Table 2. Common TAVR Imaging Tools.

	Preprocedural	Intraprocedural	Postprocedural
TTE	• Diagnose severe aortic stenosis • Assess impact of aortic stenosis on cardiac function	• Provide imaging guidance for prosthetic placement • Evaluate cardiac anatomy and function during catheterization and immediately after prosthetic implantation • Monitor for complications (eg, PAR)	• Monitor for complications (eg, PAR) in the long term
TEE	• Size the aortic valve annulus, sinus of Valsalva, and the ascending aorta	• Provide imaging guidance for prosthetic placement • Evaluate cardiac anatomy and function during catheterization and immediately after prosthetic implantation • Monitor for complications (eg, PAR)	
CT scan	• Size the aortic valve annulus, sinus of Valsalva, and the ascending aorta		
Fluoroscopy		• Provide imaging guidance for cardiac catheterization	

Abbreviations: TAVR, transcatheter aortic valve replacement; TTE, transthoracic echocardiography; TEE, transesophageal echocardiography; CT, computed tomography; PAR, paravalvular aortic regurgitation.

with the ilioinguinal and iliohypogastric nerve block. Stroke within 24 hours of the procedure occurs in 1.4% of patients and may be diagnosed and treated earlier with sedation that allows for a neurological assessment immediately after deployment.[46]

With some major complications including annular rupture and aortic dissection, the surgeon may decide not to convert to sternotomy particularly in a subset of patients who were already determined to be inoperable or high surgical risk. There are limited data regarding conversion from sedation to GA, with some studies reporting between 4.6% and 17%.[11,15,22] Gauthier et al reported a conversion rate of 6%, half of which were due to vascular injuries and half due to poor procedural cooperation.[16] Our institutional conversion rate is less than 2%.

Imaging for TAVR

Overview

Imaging is a critical aspect of TAVR; it is performed before, during, and after the procedure (Table 2). The most commonly used imaging modalities are TTE, TEE, fluoroscopy, and CTA.[47] Outpatient TTE remains the primary mode for verifying the diagnosis of aortic disease preoperatively, thereby making a patient eligible for the TAVR procedure. In addition, the preliminary TTE establishes whether or not adequate imaging windows are present for an intraoperative examination. For cases where echocardiographic windows are poor, other intraprocedural imaging modalities, such as TEE, must be considered. Once

TAVR is chosen, the aortic valve annulus, sinus of Valsalva, and the ascending aorta are sized, most commonly using CTA with intravenous contrast. TEE may be performed instead if a patient has contraindications to the use of contrast dye, such as renal insufficiency or allergy.

During the procedure, fluoroscopy is used for vascular access and to help guide the catheter to the aortic valve. Next, echocardiography assists in the proper placement of the prosthetic valve, with a focus on minimizing PAR, a predictor of post-TAVR mortality.[48] Fluoroscopy may also assist in evaluation of valve competency, position, and to rule out vascular injury as catheters are withdrawn. Routine TTE is not performed before hospital discharge although TTE is employed for long-term surveillance of the prosthesis and its impact on cardiac function.

Historically, TEE has been used as the preferred modality over TTE for intraprocedural echocardiographic imaging in TAVR, although both modalities have their advantages (Table 3). There is no doubt that TEE often provides higher quality images and has stronger 3-dimensional capabilities compared with TTE.[49] Although rare, the invasive nature of TEE introduces serious risks, including dental damage, pharyngeal laceration, and tracheal or esophageal rupture. These potential complications are particularly devastating in the typical elderly TAVR patient with multiple comorbidities. The TEE probe also increases the risk of airway obstruction in patients with an unprotected airway.

TTE has already proven to be an effective imaging tool for procedural guidance in balloon aortic valvuloplasty[50] and there is literature reporting its efficacy in TAVR. In a

Table 3. Intraprocedural Echocardiography.

	TTE	TEE
Advantages	• Noninvasive • 2D and Doppler TTE is the primary mode of diagnosing aortic stenosis and evaluating its impact • Better safety profile compared to TEE	• Higher image resolution • 3D TEE is more technologically developed than 3D TTE • No restrictions on TAVR vascular access • Minimal impact on surgical field sterility
Disadvantages	• Imaging quality is variable, depending on the availability of imaging windows as well as patient factors (obesity, hyperinflation of lungs, chest deformity) • Posterior PARs may be shadowed by prosthesis • Percutaneous transfemoral TAVR approach is preferred • Possible impact on the sterile surgical field, minimized with sterile TTE probe covers	• Semi-invasive • Risk of mechanical injuries to the oropharynx, esophagus, and stomach • Risks associated with general anesthesia

Abbreviations: TTE, transthoracic echocardiography; TEE, transesophageal echocardiography; PAR, paravalvular aortic regurgitation.

retrospective study performed by Sengupta and colleagues, TAVR procedures using TTE and sedation showed no changes in procedural success or rate of complications while also decreasing procedure time compared to TAVR procedures using TEE and GA.[51] While sterility during TTE examination remains a concern, commercially available plastic covers for the TTE probe can be used to avoid compromising the surgical field. Furthermore, emerging technology of robotic TTE may greatly improve sterility during imaging.[52] With proper preoperative selection of patients, specifically those with adequate imaging windows, TTE provides the necessary information on the location and performance of the replacement valve, including its position within the aortic root and its impact on nearby cardiac structures including the anterior leaflet of the mitral valve, left ventricular outflow tract, and coronary arteries.

Intraprocedural Echocardiography

On entering the room a concise examination is performed by a physician echocardiographer independent of the anesthetic team and compared with prior reports. It is essential to become familiarized with each patient's echo windows so that optimal imaging can be acquired expeditiously if needed emergently later in the case. Factors that can result in poor image quality are well known and include obesity, hyperinflated lungs, and chest deformities.

First, the parasternal long axis is used to confirm presence of aortic disease and quantify aortic regurgitation with color flow Doppler (Figure 2). Measurements of the left ventricular outflow tract (LVOT), aortic root, and aortic annulus in this view are compared to previous imaging. These may be required for valve sizing. Baseline mitral regurgitation is quantified for comparison with post deployment studies. The x-plane function with a 3-dimensional probe allows visualization of the parasternal short axis at the level of the papillary muscles to evaluate left ventricular (LV) function. Parasternal short axis at the level of the mitral valve allows for evaluation of basal LV segments, and parasternal short axis at the level of the aortic valve can be used to further define aortic regurgitation. The presence of a pericardial effusion at baseline should be noted and is usually best visualized in the subcostal 4-chamber view with full inspiration.

The apical 4-chamber view is next obtained to further evaluate for the presence of mitral regurgitation, and is combined with the apical 2-chamber to evaluate the apical segments of the LV. The apical 5-chamber view is then used to acquire LVOT and aortic valve pressure gradients to derive an aortic valve area and stroke volume. These measurements may be challenging due to an inability to position the patient in the left lateral decubitus position. In the supine position, the heart is farther from the TTE probe and the lungs are positioned in between the two. Imaging during complete expiration in a cooperative patient may be helpful. Frequently, a more lateral off-axis view is required. The apical 3-chamber view may also be helpful.

Intraoperative TTE is critical for confirming that the prosthesis has been properly deployed. For self-expanding systems, the parasternal long access can be used to quickly evaluate for device malfunction, PAR, and depth of implantation into the LVOT after partial valve deployment. This allows for recapture and adjustment when necessary.
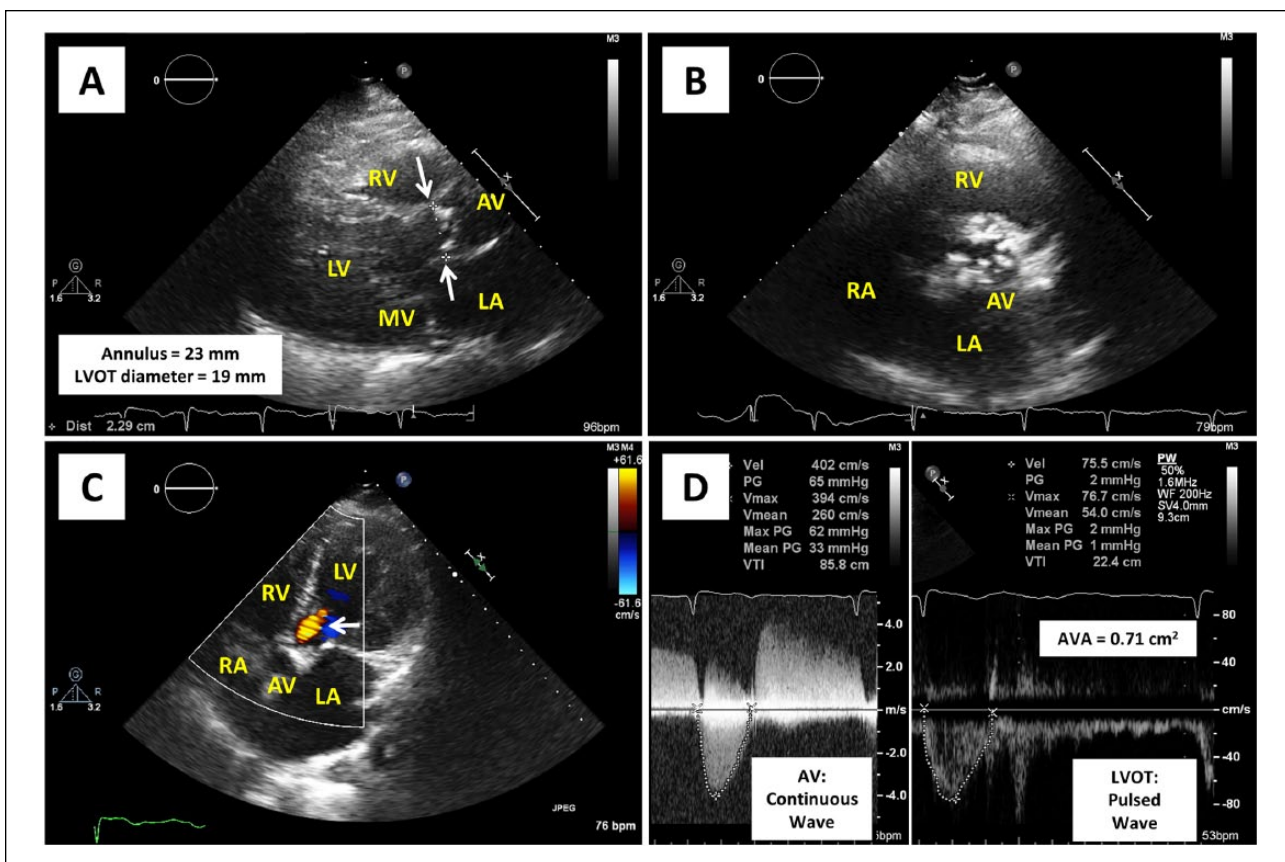
Figure 2. TTE imaging immediately prior to TAVR is used to confirm the diagnosis of severe aortic stenosis and remeasure aortic root parameters including aortic annulus.

Panel A – Parasternal long axis view demonstrates a heavily calcified aortic valve as well as a measurement of the aortic annulus (arrows).

Panel B – Parasternal short axis view demonstrates a heavily calcified trileaflet aortic valve.

Panel C – Apical 5-chmaber view with color Doppler demonstrates mild native aortic valve regurgitation (arrow).

Panel D – Spectral Doppler recordings from the apical 5-chamber view confirm the diagnosis of severe aortic stenosis. Note the high peak AV velocity (> 4 m/sec), markedly decreased AV area (<1.0 cm2) and a very low dimensionless velocity index (the ratio between the peak LVOT velocity and the peak AV velocity) in this patient: 0.76 / 4.02 m/sec = 0.19.

Balloon-expandable systems cannot be adjusted once deployed; however, the parasternal long axis should be obtained to confirm ideal positioning, with approximately 50% of the valve system on each side of the native aortic valve annulus. Parasternal short axis and apical 5 chambers should then be used for evaluation of paravalvular and transvalvular aortic regurgitation using color flow Doppler (Figure 3). Posteriorly located PAR can be shadowed by the prosthesis and thus multiple views must be obtained. One cause of PAR may be incomplete deployment, which is seen on echo as a non-circular appearing stent. The treatment for incomplete expansion is post deployment balloon aortic valvuloplasty. Final gradients and velocities are measured across the new valve using spectral Doppler. Worsening mitral regurgitation or new intracardiac shunt should be ruled out. Each patient should be evaluated for postprocedure pericardial effusion with or without tamponade, and if present, TTE can be used to guide pericardiocentesis.[53] Whenever a diagnosis is in doubt, a TEE probe should always be available to provide additional echocardiographic views.

Conclusion

As cardiac procedures become less invasive, the cardiac anesthesiologist is tasked with evolving in parallel.[54]

Management of aortic valve disease with TAVR has changed rapidly as technological advancement and additional experience has improved patient outcomes. Despite the absence of randomized trials, there is strong evidence suggesting the use of sedation is safe, feasible, and beneficial for the majority of patients. We have reviewed the anesthetic management of patients undergoing TAVR and advocate for the avoidance of GA as described in this review.
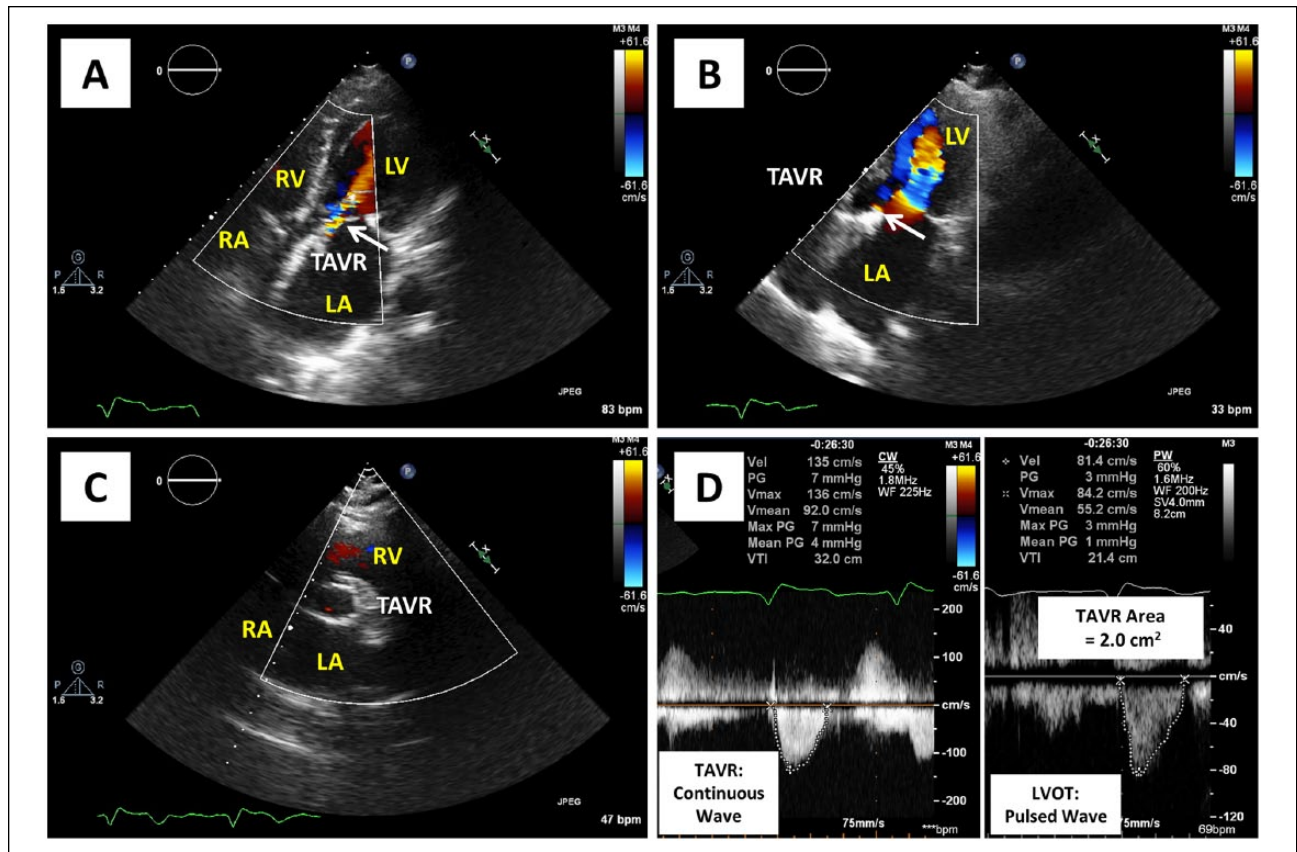
Figure 3. TTE imaging during and post TAVR is used to assess for proper placement of a TAVR valve with a special emphasis on the detection and quantification of paravalvular aortic regurgitation.

Panel A – After initial placement of a CoreValve Evolut R there is moderate paravalvular aortic regurgitation (arrow) in the apical 5-chamber view.

Panel B – Following postdilation of the TAVR valve in Panel A, paravalvular aortic regurgitation is reduced to trace (arrow) in the apical 5-chamber view.

Panel C – Parasternal short axis view with color Doppler demonstrates that the deployed CoreValve has proper circular shape and no paravalvular aortic regurgitation is seen.

Panel D – Spectral Doppler recordings from the apical 5-chamber.

Declaration of Conflicting Interests

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