ROLE OF TEE IN TRANSCATHETER AORTIC VALVE REPLACEMENT (TAVR), AORTIC VALVE REPAIR, AND VALVE-SPARING AORTIC ROOT REPLACEMENT

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Introduction

Transcatheter aortic valve replacement (TAVR), aortic valve repair, and valve-sparing aortic root replacement are emerging technologies for the surgical treatment of aortic valve and aortic root disease. Intraoperative transesophageal echocardiography (TEE) has played an important role in both the development and continued refinement of each of these procedures. In contemporary practice, intraoperative TEE provides useful information to assess the feasibility and planning of TAVR, aortic valve repair, and valve-sparing aortic root replacement. Immediately after the procedures, intraoperative TEE is used to assess valve function, determine the need for further intervention, and to diagnose complications.

Transcatheter Aortic Valve Replacement (TAVR)

Transcatheter aortic valve replacement (TAVR) is a procedure for catheter-based delivery and implantation of a stent-mounted bioprosthetic aortic valve into the aortic position for the treatment of patients with degenerative aortic stenosis. TAVR can be performed using the retrograde approach where the stent-mounted valve is delivered from a catheter via the femoral artery, axillary artery, or descending aorta or using an antegrade approach where the stent-mounted valve is delivered through the left ventricular apex. Following balloon aortic valvuloplasty, the prosthetic valve is positioned across the aortic valve annulus using TEE and fluoroscopic guidance prior to deployment. After deployment, the prosthetic aortic valve is held in place within left ventricular outflow tract and the aortic root by radial forces with the native aortic valve cusps sandwiched between the prosthetic valve stent and the wall of the aortic root.

The TAVR procedure is currently being performed in clinical trials for patients with severe degenerative aortic stenosis deemed to be inoperable or high risk for conventional surgical aortic valve replacement. Echocardiography is used to quantify the severity of aortic stenosis to determine eligibility for the procedure (peak transvalvular flow velocity >4 m/s, peak transvalvular pressure gradient > 64 mm Hg, mean transvalvular pressure gradient > 40 mm Hg, and aortic valve area <0.8 cm² or indexed aortic valve area <0.5 cm²/m²). Echocardiographic examination is also used to determine ineligibility for TAVR by detecting the presence of significant aortic regurgitation (>3+), unicuspid aortic valve, bicuspid aortic valve, subaortic stenosis, left ventricular outflow tract obstruction, severe left ventricular dysfunction (LVEF<20%), intracardiac thrombus, or severe mitral regurgitation that are exclusion criteria for TAVR. The presence of severe atherosclerosis in the ascending thoracic aorta or aortic arch with protruding or mobile
atheroma may also prohibit TAVR or require antegrade delivery through the left ventricular apex.

In preparation for the TAVR procedure, TEE in combination with preoperative multidetector CT scan or MRI is used to measure the diameter of the aortic valve annulus to determine the size of the prosthetic valve for implantation. With currently available TAVR prosthetics, the patient must have an aortic annular diameter at least 18 mm. Aortic valve annular diameter is measured using the mid-esophageal aortic valve long axis view in systole from the basal attachment of the valve cusps at the annulus. Measurement of the aortic valve annular diameter should not include annular calcification protruding into the left ventricular outflow tract. The mid-esophageal aortic valve long axis view provides a measurement of the aortic annular diameter from the non-coronary/left coronary commissure to the base of the right coronary cusp and may not correlate exactly with annular diameters measured by CT or MRI imaging. Precise sizing of the aortic valve annular is important for determining the proper size of the TAVR prosthesis. An undersized TAVR prosthesis increases the risk of paravalvular regurgitation or dislodgement. Oversizing the TAVR prosthesis increases the risk of aortic root rupture or transvalvular regurgitation due to incomplete deployment.

During balloon valvuloplasty (BAV) and catheter positioning of the TAVR, intraoperative TEE is used together with fluoroscopy to position the balloon and TAVR prosthesis within the aortic valve annulus. TEE is useful during this part of the procedure to direct and position the guidewires across the native aortic valve. TEE guidance is especially important for transapical delivery to ensure that the guidewire and catheter is not entangled within the mitral subvalvular apparatus. During valve positioning, TEE together with fluoroscopy can be used to position the catheter mounted valve across the native aortic annulus immediately prior to deployment.

Immediately after TAVR deployment, TEE is used to detect paravalvular and transvalvular aortic regurgitation. Paravalvular regurgitation can be caused by annular and cusp calcification or malposition of the prosthetic valve. Transvalvular regurgitation can be caused by restriction of the prosthetic valve cusps by the guidewire through the valve, incomplete deployment of the valve with crimping of the prosthetic cusps within the valve, or a trapped valve cusp within the stent. The location and severity of paravalvular regurgitation is important to determine if it can be treated by repeat balloon expansion of the valve or deployment of a second valve (valve within valve). TEE assessment of aortic regurgitation is performed with Doppler color flow imaging using the mid-esophageal aortic valve long axis, the mid-esophageal aortic valve short axis, and the transgastric aortic valve long axis views. Assessment of aortic regurgitation by TEE using orthogonal cross sectional imaging planes and from the left ventricular side of the valve is necessary to avoid failing to detect a significant paravalvular leak because of acoustic shadowing from the prosthetic valve. Mild paravalvular regurgitation with regurgitant jets that do not extend past the tip of the anterior mitral valve leaflet and without a region of proximal convergence may not require treatment.
After successful TAVR and valve deployment, TEE can be used to measure the gradient across the prosthetic valve and to estimate the effective orifice area. In addition, TEE is useful to detect complications of TAVR. Acute ventricular dysfunction or new segmental wall motion abnormalities may indicate coronary occlusion by the valve stent. New or worsening of mitral regurgitation may indicate injury to the mitral valve apparatus. A new pericardial effusion or cardiac tamponade may indicate ventricular or aortic perforation by guidewires or catheters or even disruption of the aortic root. The thoracic aorta should be examined to verify the absence of iatrogenic aortic dissection. TEE assessment of ventricular size and function can also be useful during resuscitation in response to vascular injury at the access site.

**Aortic Valve Repair**

Surgical techniques for aortic valve repair for aortic regurgitation are continually evolving in response to an increased effort to avoid the problems associated with prosthetic AVR such as thromboembolism and structural valve degeneration. The routine use of intraoperative TEE has also increased the feasibility and success of aortic valve repair by characterizing valve pathology pruding aortic regurgitation and assessing the success of the repair.

In planning aortic valve repair, TEE is used to identify and characterize the functional causes of aortic regurgitation. The three main causes or aortic regurgitation are dilation of the aortic root (type 1), excessive cusp motion or cusp prolapse (type 2), and restricted cusp motion due to calcification or fibrosis (type 3). This classification can be applied for the evaluation of normal tricuspid aortic valves or bicuspid aortic valves. Identification of the pathophysiology of aortic regurgitation permits designing the appropriate surgical repair. Type 1 aortic regurgitation caused by a dilated aortic root can be repaired by remodeling of the aortic root or reimplantation of the native aortic valve into a prosthetic aortic root with subcommissural annuloplasty. Type 2 aortic regurgitation caused by cusp prolapse can be repaired plication or triangular resection to equate the lengths of the free margins of the valve cusps. Type 3 aortic regurgitation caused by calcification or fibrosis of the valve cusp is repaired by decalcification, cusp remodeling, cusp repair, or pericardial patch augmentation. Type 3 aortic regurgitation is the most difficult to repair and achieve long term freedom from re-operation. Often commissural resuspension, root remodeling, valve re-implantation into a prosthetic root, subcommissural annuloplasty, and cusp remodeling are combined to achieve a satisfactory outcome. Because aortic regurgitation may be associated with disease of the ascending aorta or aortic arch, aortic valve repair may be combined with ascending aorta or aortic arch replacement.

The TEE examination for aortic valve repair should include precise measurements of the diameters of the aortic valve annulus, sinus of Valsalva, sinotubular junction, and ascending aorta. These measurements are typically obtained from the mid-esophageal aortic valve long-axis and the mid-esophageal ascending aorta short axis views. The symmetry of the aortic valve annulus, cusps, and sinuses of Valsalva can be assessed with the mid-esophageal aortic valve short axis view. The aortic valve short axis view is also
useful for the diagnosis of bicuspid aortic valve and to identify calcifications on the valve cusps. The aortic valve long axis view is used also to assess the symmetry of cusp coaptation in relation to the annular plane, to detect cusp prolapse, and to characterize cusp mobility. In the aortic valve long axis imaging plane, it is sometimes difficult to distinguish the non-coronary from the left coronary cusps, but increased experience with three-dimensional TEE imaging is helping to address this limitation. TEE Doppler color flow imaging can provide additional important information to further characterize the pathophysiology of aortic regurgitation. A central regurgitant jet with a triangular regurgitant orifice shape suggests type 1 aortic regurgitation caused by dilation of the aortic root. An eccentric regurgitant jet suggests type 2 or type 3 aortic regurgitation. Despite high resolution multiplane and 3-D TEE, direct surgical inspection of the aortic valve cusps and aortic root is sometime necessary to identify the precise defects causing aortic regurgitation. Aortic regurgitation caused by fenestrations along the free margins of the aortic valve cusps are often difficult to distinguish from cusp prolapse using TEE imaging alone.

TEE examination immediately aortic valve repair has been shown to be useful for predicting the durability of the repair or the risk of recurrent aortic regurgitation requiring re-intervention. TEE findings that indicate a successful repair are trace or no residual aortic regurgitation, aortic valve cusp coaptation on the aortic side of the annular plane, and a cusp coaptation margin length of greater than 4 mm. Optimal restoration of aortic root anatomy and aortic valve coaptation can also be defined by the effective cusp height or the distance between the tips of the cusps and the annular plane in diastole. An effective cusp height of greater than 8 mm suggests an satisfactory margin of coaptation greater than 4 mm in length and the absence of residual prolapse. The presence of even mild residual aortic regurgitation by TEE after repair was consistently shown to be a risk factor for recurrent aortic regurgitation. Rarely, aortic valve repair may cause aortic stenosis that can be detected and quantified by TEE measurement of aortic valve gradient and effective orifice area after repair.

Valve-Sparing Aortic Root Replacement

Aortic valve repair is often necessary in patients with thoracic aortic disease requiring replacement of the aortic root and ascending aorta even in the absence of significant aortic regurgitation. If the aortic valve is functioning normally, prosthetic AVR can be avoided by re-implantation of the native aortic valve into the new prosthetic aortic root (valve-sparing aortic root replacement). This procedure is commonly performed for patients with aortic root and ascending aortic aneurysm from Marfan’s disease or congenital bicuspid aortic valve. The TEE assessment of aortic valve function before and after re-implantation follow the same principles outlined above for the assessment of aortic valve repair for aortic regurgitation.

Selected References


