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Review Article

The role of transesophageal echocardiography in clinical use

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Abstract

Transesophageal echocardiography (TEE) is not only an invaluable diagnostic tool for cardiac patients, but also is essential for cardiac monitoring in critically ill patients in cardiac and non-cardiac surgery settings and in the differential diagnosis of unexplained hemodynamic collapse. The advantage of TEE over transthoracic echocardiography (TTE) is usually clearer images, especially when viewing structures that are difficult to see transthoracically. TEE is essential in monitoring adult and congenital heart surgery perioperatively. The adequacy of the repair can be ensured immediately through a review of TEE images directly after surgery. Although TEE is considered to be relatively safe and noninvasive, TEE-associated complications, such as esophageal laceration, must be taken seriously. Recently, real-time three-dimensional (3D) TEE imaging has played an important role defining valvular and congenital abnormalities and aiding in operative and percutaneous repair.

Keywords: cardiac surgery; catheter intervention; critical care; transesophageal echocardiography

1. Introduction

Echocardiography is the most frequently used diagnostic tool for real-time imaging of cardiac structure and function. In the last decade, transesophageal echocardiography (TEE) has become essential in cardiac surgery, and has expanded its role in other areas of patient care.[1–5] TEE is performed by inserting a probe with a transducer into the esophagus, and offers superior visualization of posterior cardiac structures, because of the close proximity of the esophagus to the posteromedial heart, without visual interference from the lung and skeleton. In 1976, Frazin et al[6] first introduced the clinical use of TEE when a modified rigid endoscopic probe with a single M-mode crystal was used. In 1980, the phased-array ultrasound transducer was introduced, and it was later reduced in size. The process of implementing biplane probes[7–9] by using crystal miniaturization with color Doppler is the standard principle used in echocardiography. In 1990, multiplane TEE probes become available, utilizing mechanical or electronic rotation of the 180 degree scanning plane.[10–13] Remarkable progress in TEE probe technology has been made in the last 10 years. More recently, real-time three-dimensional (3D) imaging has been available by using a matrix array ultrasound probe and an appropriate processing system.[14] This enables detailed anatomical assessment of cardiac pathology and particularly valvular defects.[15] Now, TEE is a well-established and standard diagnostic technique in the operating room, intensive care unit, and laboratory catheter room.

2. Indication of TEE

TEE can reveal new findings that necessitate cross-checking perioperatively, such as mitral valve (MV) disorders, blood clots or intracardiac masses, dissection of the aorta, and implanted prosthetic (artificial) heart valves. In 1996, a joint task force of the American Society of Anesthesiologists (ASA) and the Society of Cardiovascular Anesthesiologists (SCA) published guidelines for the perioperative

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application of TEE.[16,17] Based upon the current ASA and SCA guidelines, category I indications of perioperative TEE are:

1. Intraoperative evaluation of acute, persistent, and life-threatening hemodynamic disturbances in which ventricular function and its determinants are uncertain and have not responded to treatment.
2. Intraoperative use in valve repair.
3. Intraoperative use in congenital heart surgery for most lesions requiring cardiopulmonary bypass.
4. Intraoperative use in repair of hypertrophic obstructive cardiomyopathy.
5. Intraoperative use for endocarditis when preoperative testing was inadequate or extension of infection to perivalvular tissue is suspected.
6. Preoperative use in unstable patients who have suspected thoracic aortic aneurysms, dissection, or disruption that needs to be evaluated quickly.
7. Intraoperative assessment of aortic valve function in repair of aortic dissections with possible aortic valve involvement.
8. Intraoperative evaluation of pericardial window procedures.
9. Use in intensive care unit for unstable patients who have unexplained hemodynamic disturbances, suspected valve disease, or thromboembolic problems.

3. Contraindications from TEE[18,19]

1. Esophageal stricture or malignancy.
2. Surgical interposition of the esophagus.
3. Esophageal diverticulum.
4. Cervical spine arthritis with reduced range of motion.
5. Severe thrombocytopenia (<50,000/μL), elevated international normalized ratio (>4), or prolonged partial thromboplastin time (>150 seconds).

4. Tomographic views of TEE[20]

Several tomographic views are commonly used. A complete TEE examination should include imaging of all cardiac chambers, valves, and great vessels. A standard comprehensive approach to imaging is recommended, but each individual study should be modified to reflect the specific clinical indication. Each tomographic view is defined by the transducer position in the esophagus, which will view the TEE images of the mid-esophageal view (at the mid-esophageal position) including four chamber, five chamber, two chamber, short-axis, long-axis, two caval views (Fig. 1-**1**), upper esophageal view (at upper esophageal position) (Fig. 1-**2**) and transgastric view at the gastric position (Fig. 1-**3**).

Current TEE probes allow for both 2D and 3D imaging, as well M-mode, spectral Doppler, and color Doppler.

4.1. 2D echocardiography

2D TEE provides tomographic or "thin slice" imaging, with each tomographic view defined by the transducer position. The technique is used to visualize the actual structures and the real-time motion of the heart.

4.2. 3D echocardiography

3D TEE capability has been developed to overcome the disadvantages of 2D tomography. 3D TEE was first described in the 1970s, because the acquisition of ECG and respiratory-gated 2D images, which subsequently required off-line reconstruction, was very time-consuming. However, the matrix TEE probe, introduced clinically in 2007, can quickly and easily collect real-time 3D images, enabling the echocardiographer to provide an entire view that contains all pertinent information and real time images. This in turn results in better understanding and facilitating of decision making during the cardiac catheterization procedures and cardiac surgery.

These systems generally acquire a volumetric data set, which can then be displayed in custom orientations. The technique captures 3D views of the heart structures with greater depth than 2D echocardiography.

4.3. M-mode echocardiography

M-mode can provide additional information for characterizing the motion of cardiac structures. To ensure proper alignment and reproducibility, all M-mode recordings are performed with 2D guidance. M-mode echo is useful for measuring heart structures, such as the heart's pumping chambers, the size of the heart, and the thickness of the heart walls.

4.4. Doppler echocardiography[8]

This technique is used to measure and assess the flow of blood through the heart's chambers and valves. Doppler echocardiography has the ability to estimate the pressure difference across a stenotic valve (e.g., aortic stenosis) or between two chambers (e.g., estimation of the pulmonary artery systolic pressure from the tricuspid regurgitation velocity). The modified Bernoulli equation (Delta $P = 4_* V^2$) is the most commonly used application relating peak velocity to peak pressure gradient. There are several Doppler methods used for cardiac evaluation-continuous wave, pulsed wave, and color flow.

4.5. Color Doppler[8]

Color flow imaging is typically used in the screening and assessment of regurgitant flows, intracardiac shunts, and pulmonary vein flow. Different colors are used to designate the direction of blood flow.

5. TEE in clinical applications

5.1. Critical care[21–24]

TEE can be performed quickly at the bedside in critically ill patients with unexplained hypotension, unexplained hypoxemia, uncertain volume status, and blunt chest trauma.

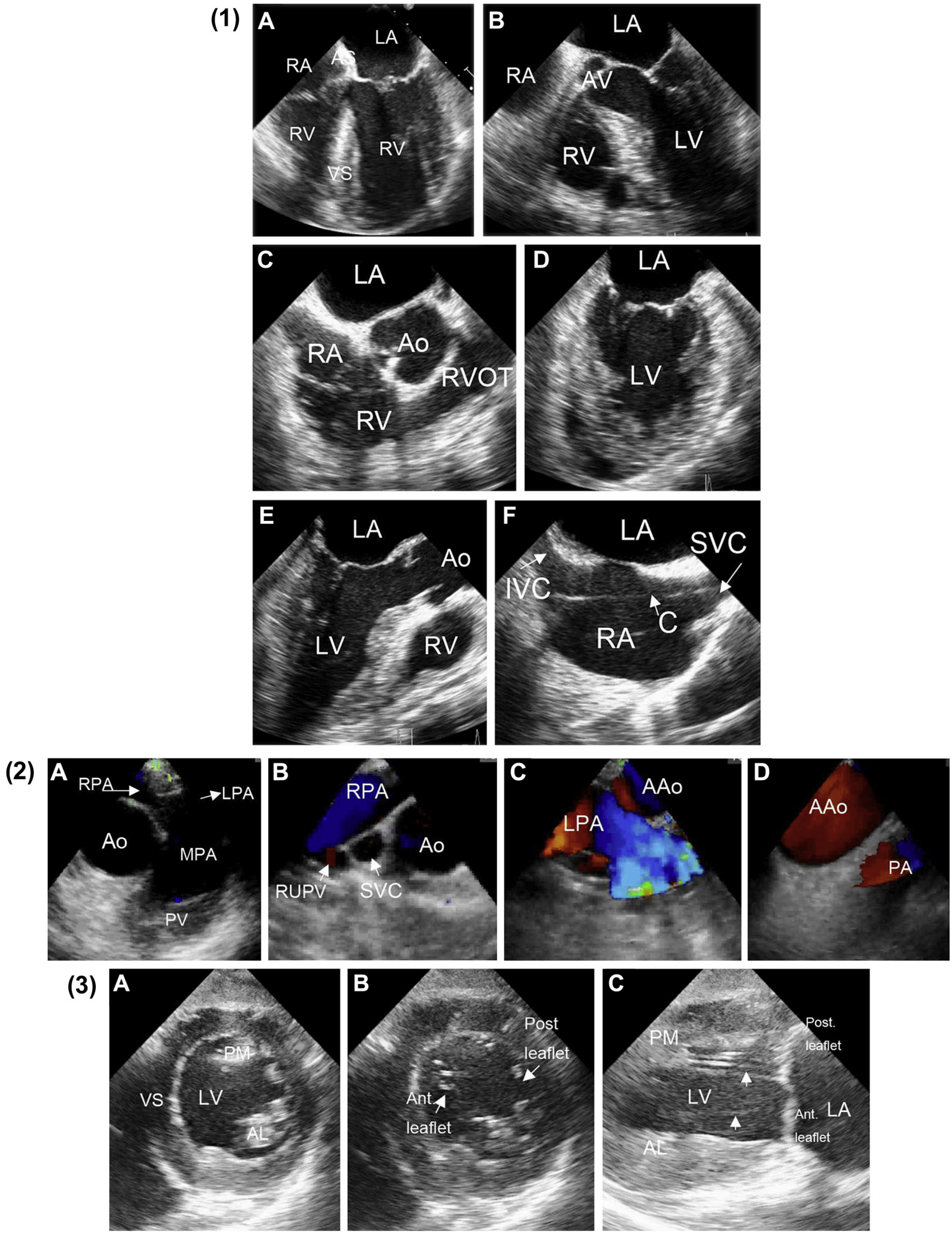

Fig. 1. (1) The mid-esophageal views of transesophageal echocardiography (TEE). (A) Four chamber view at 0 degrees; (B) five chamber view at 0 degrees; (C) right ventricle (RV) inflow-outflow view at 80 degrees; (D) two chamber view at 90 degrees; (E) left ventricle (LV) long axis view at 120 degrees; and (F) bicaval view at 90–120 degrees. **(2)** The upper-esophageal views of TEE. (A) main pulmonary artery (MPA); (B) right pulmonary artery (RPA); (C) left pulmonary artery (LPA); and (D) ascending aorta (AAo). **(3)** The transgastric views of TEE. (A) short axis view for papillary muscle; (B) short axis view for mitral leaflet; and (C) long axis view for chordae apparatus (arrow). AL = anterolateral papillary muscle; Ao = aorta; AV = aortic valve; C = central venous catheter; IVC = inferior vena cava; LA = left atrium; LV = left ventricle; PA = pulmonary artery; PM = posteromedial papillary muscle; PV = pulmonary valve; RA = right atrium; RUPV = right upper pulmonary vein; RV = right ventricle; RVOT = right ventricle outflow tract; SVC = superior vena cava; VS = ventricular septum.

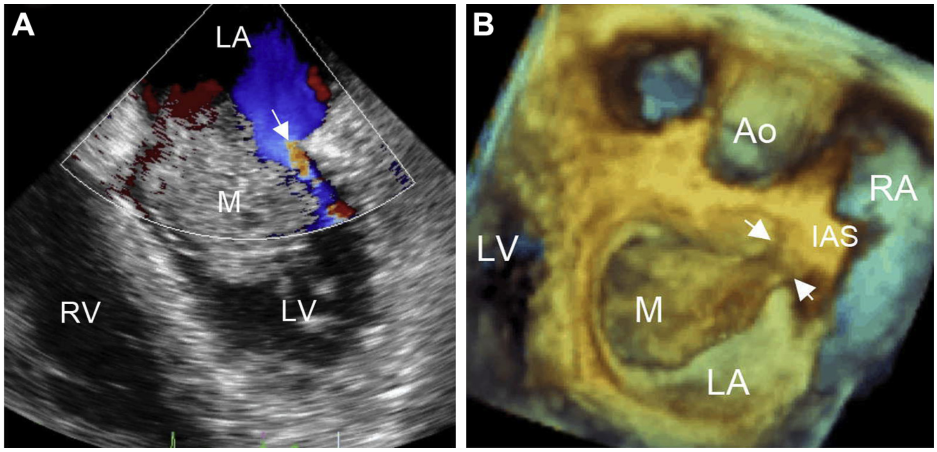

Fig. 2. (A) A case of left atrial myxoma (M) with obstruction of the left ventricle inflow and minimization of the flow (arrow) toward the left ventricle; (B) enface left atrium view of real-time three-dimensional transesophageal echocardiography (TEE) shows a pedicle of the myxoma (arrow) attached to interatrial septum and protruding through the mitral valve. Ao = aorta; IAS = interatrial septum; LA = left atrium; LV = left ventricle; RA = right atrium; RV = right ventricle.

5.1.1. *Air embolism*[25,26]

Air embolism is an uncommon, but potentially catastrophic complication. Venous air embolism complicates laparoscopic procedures, orthopediatric, or neurosurgical procedures whenever the surgical incision site is above the level of the patient's heart, such that pressure in the veins is subatmospheric. TEE may play an important role and is more sensitive for detecting intracardiac air resulting from venous air embolism.

5.1.2. *Pulmonary thromboembolism*[27,28]

Pulmonary embolism (PE) is the third most common cardiovascular disease after myocardial infarction and stroke. Approximately 90% of all pulmonary thromboemboli originate from deep veins of the lower extremities. Deep venous thrombosis and PE constitute venous thromboembolism. Fortunately, central pulmonary emboli are directly visualized with TEE.

TEE may play a primary role in patients who have suspected massive emboli and are too unstable to transfer elsewhere for CT imaging examination, or for ventilation–perfusion scanning.

5.1.3. *Blunt chest trauma*[29]

Blunt cardiac injury occurs most often from motor vehicle collisions. Patients with clinical or echocardiographic evidence of severe cardiac injury (e.g., ruptured valve, septum, or ventricular wall; cardiac tamponade) require emergent surgical consultation.

5.1.4. *Penetrating injuries of the heart*[30]

Penetrating injuries of the heart are caused by stab or gunshot wounds, or the rare accidental impalement. Unlike blunt cardiac injuries, the heart or great vessels should be immediately suspected in any patient suffering from penetrating trauma of the chest. Most patients' hemodynamics are unstable in the field and many present to the emergency department receiving cardiopulmonary resuscitation.

5.1.5. *Cardiac arrest*[22,27]

Management of the post-cardiac arrest patient is complex and must address multiple major problems simultaneously. TEE provides a clear view of cardiac wall motion abnormalities, valvular or septal injuries, or pericardial disease.

5.2. *Cardiac surgery*

In surgical management, TEE can reveal new findings that necessitate reconfirmation. It is indispensable to early

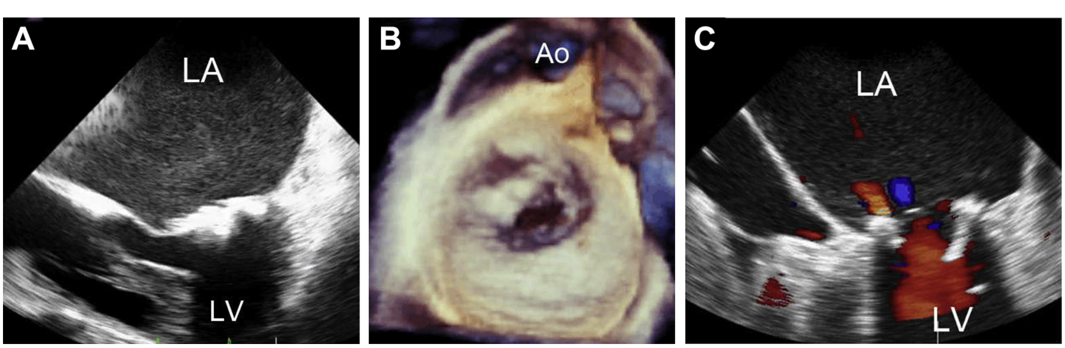

Fig. 3. (A) Two-dimensional (2D) transesophageal echocardiography (TEE) (apical 4-chamber view) in a patient with rheumatic mitral stenosis shows fusion of commissures and vegetation formation; (B) fish mouth shape of mitral valve orifice is delineated by 3D TEE enface LA view; and (C) mitral stenosis is replaced by prosthetic tissue mitral valve. Ao = aorta; LA = left atrium; LV = left ventricle.

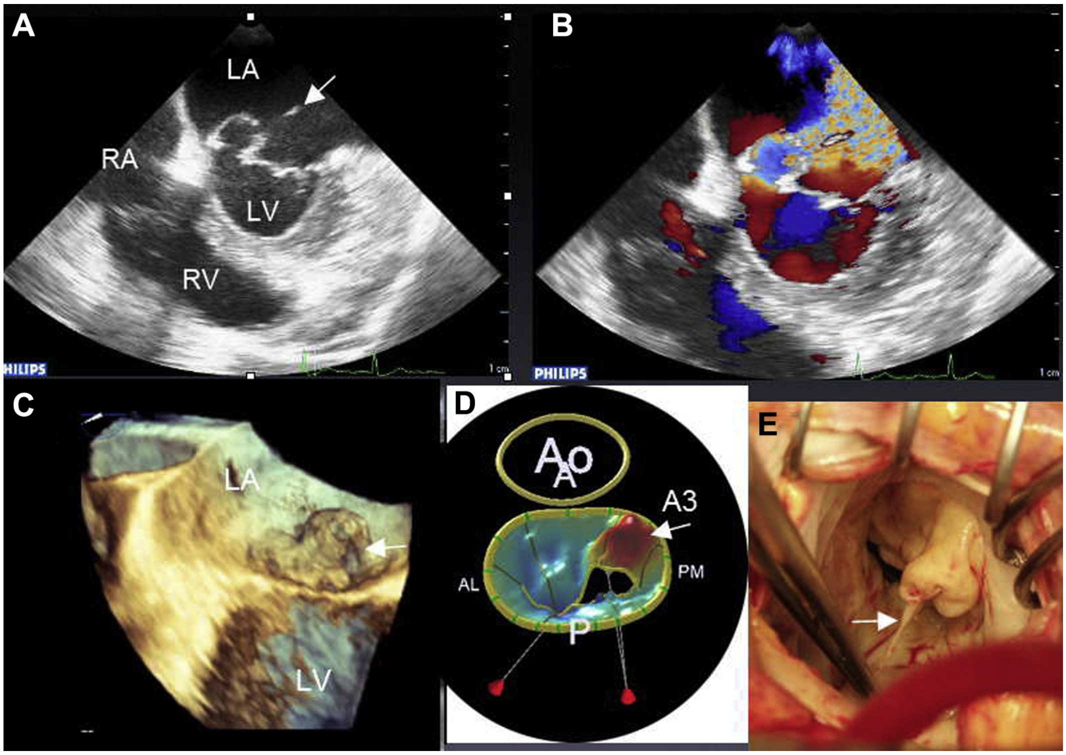

Fig. 4. Mitral regurgitation. (A) Four-chamber apical view of a two-dimensional (2D) transesophageal echocardiography (TEE) demonstrates anterior leaflet prolapse with ruptured chordae (arrow); (B) color Doppler apical four-chamber view shows severe mitral regurgitation with the regurgitant jet hitting the distant wall of the left atrium and encircling it, as well as traversing back into the pulmonary veins; (C) 3D TEE demonstrates the height of the A3 flail (arrow); (D) prolapse of A3 is reconstructed mitral valve using Mitral Valve Quantification software (MVQ) (Advanced Quantification Software version 7.1, Philips Ultrasounds, Bothell, WA); and (E) surgeon's view: A3 cord is visualized (arrow). Ao = aorta; LA = left atrium; LV = left ventricle; RA = right atrium; RV = right ventricle.

evaluation of inadequate surgical repair and reversion without hesitation during adult and congenital heart surgery.

5.2.1. Adult cardiac surgery

In one prospective study of 474 consecutive patients undergoing coronary artery surgery, TEE prompted a change in the surgical plan in 3.4% of the patients.[31] In the absence of contraindications, TEE is indicated in virtually all cardiac surgery, because it provides an assessment of the surgical intervention in the operating room, where any needed procedural revisions can be accomplished immediately. In 205 consecutive patients undergoing posterior mitral leaflet quadrangular resection (the most common mitral repair technique), TEE revealed failures in 24 patients (11%).[32] In 20 of these patients, TEE identified the mechanism of failure and guided immediate further repair.

5.2.2. Atrial myxoma

Myxomas are the most common type of benign cardiac primary tumors. They are usually located in the left atrium

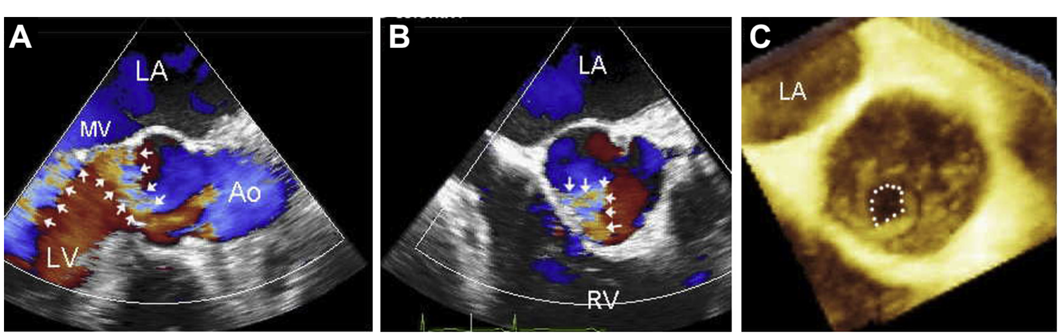

Fig. 5. Patient with aortic regurgitation with Austin Flint diastolic murmur. (A) long-axis view of transesophageal echocardiography (TEE) image shows backflow of blood from the aorta presses on the anterior leaflet of the mitral valve (multiple arrows), producing functional mitral valve stenosis; (B) the corresponding view of short axis demonstrates the regurgitant orifice on right and non-coronary cuspid (arrow); and (C) three-dimensional TEE delineates the regurgitant orifice (circle). Ao = aorta; LA = left atrium; MV = mitral valve; RV = right ventricle.

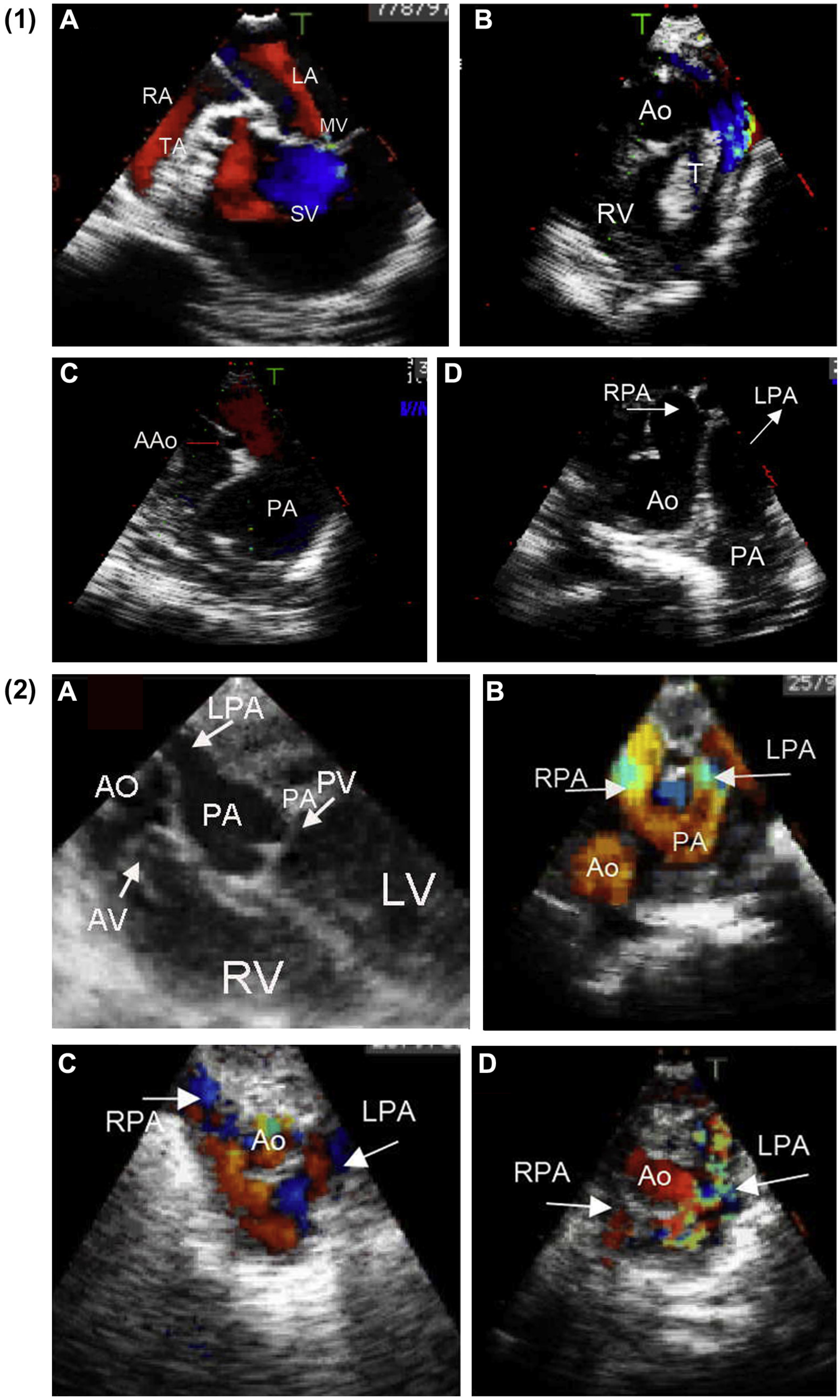

Fig. 6. **(1)** Newborn infants with complex congenital heart diseases. (A) Two-dimensional (2D) echocardiogram (apical 4-chamber view) in an infant with tricuspid atresia (TA) shows a complete absence of the tricuspid valve, right atrioventricular connection, and single ventricle; (B) four-chamber view in an infant with a rhabdomyoma of the heart shows echogenic mass (T) attached to the interventricular septum and reducing the size of the outflow tract; (C) an infant with hypoplastic left heart syndrome demonstrates a hypoplastic aorta (Ao) and a huge pulmonary artery (PA); and (D) an infant with hemitruncus arteriosus shows the right PA (RPA) originating from the ascending Ao (AAo) and the left PA (LPA) from the pulmonary artery (PA). **(2)** A newborn with transposition of great arteries

(Fig. 2) and attached to the interatrial septum. They may cause mitral obstruction, systemic emboli, or life-threatening complications, such as heart failure, syncope, or sudden death. TEE is used to assess the location of tumor attachment and measure the size of the mass to better facilitate surgeons as they move to complete the operation.

5.2.3. MV diseases[33–36]

MV repair surgery has become more common in the last decade, constituting more than half of MV procedures. Its feasibility depends on the location, extent, and mechanism of MV disease. Perioperative monitoring of MV anatomy, function, and pathology is essential for surgical management of different MV disease. 3D TEE allows visualization of the anatomic structure of the heart to be online and clearly identifies the valvular apparatus and its defects, which mimic actual anatomy as viewed by the surgeons *in situ*. We conclude that real-time 3D TEE should be regarded as an important adjunct to the standard 2D TEE examination in making decisions perioperatively.

5.2.3.1. Mitral stenosis. In mitral stenosis, the normal, rapid, biphasic motion of the valve is altered, because the valve opens only partly to a certain degree. TEE can identify the pathologic entity of mitral stenosis and quantitate its severity with sufficient accuracy to make reliable decisions (Fig. 3). Doppler methods can measure the velocity of mitral inflow. In mitral stenosis, this velocity increases at rest from a normal value of <1 m/second to >1.5 m/second. The 2006 ACC/AHA guidelines on valvular heart disease defined severe mitral stenosis as having a mean transmitral gradient >10 mmHg, pulmonary artery systolic pressure >50 mmHg, and an MVA <1.0 cm^2.

5.2.3.2. Mitral regurgitation. 2D TEE was routinely used for planning of MV regurgitation surgery. However, in complex valvular pathologies, 2D TEE has several potential pitfalls with regard to spatial relationships and valvular morphological abnormalities. In our previous study, real-time 3D/2D TEE was used to assess 73 patients (44 men and 29 women) with Carpentier type II MV regurgitation undergoing MV surgery perioperatively. The isolated segment most frequently involved was A2 or P2, but A1 or P1 rarely was involved in an isolated lesion or combined with other lesions. The agreement between 3D TEE finding and surgery was 88% (64/73) (Fig. 4).[33]

In addition, retrograde systolic left atrial flow, caused by the swirling of a large regurgitant eccentric jet, is commonly noted in patients with a flail MV leaflet. 2D TEE color Doppler is the most widely used method for assessing the seriousness of mitral regurgitation (MR) and positioning the lesions. The severity of MR that produces eccentric rather than central jet flows can be underestimated on 2D TEE Doppler images. Moreover, it can often be challenging to identify which mitral leaflet is affected via 2D TEE color Doppler in patients with very eccentric MR jets. In contrast, RT 3D TEE can provide a true cross-section view of the MV and is therefore a powerful tool during surgical repair of the MV. In our study of 168 MR patients, 25 patients (14.9%) had central jets and 143 patients (85.1%) had eccentric jets. Among the 143 patients with eccentric jets, 47 patients (32.9%) had free-standing eccentric MR jets, and 96 (67.1%) patients had very eccentric jets. 3D TEE diagnosed the severity and location of MR lesions correctly in all patients, unlike 2D TEE, which significantly missed in nine patients (9.4%) having MR with very eccentric jets, due to such highly turbulent MR flow produced by very eccentric jets from one mitral leaflet lesion and impinging on the opposite mitral leaflet lesion.[15]

Furthermore, prosthetic paravalvular regurgitant can result in heart failure and hemolytic anemia. Echocardiography remains the main modality for the diagnosis of prosthetic valve dysfunction. 2D TEE represents only a slice through the cardiac tissue, which resulted in the missing of significant findings. However, real-time 3D TEE can provide a more accurate assessment of the exact site and size of the leakage while closing the defect or revision surgery.

5.2.4. Aortic valve diseases[37]

TEE has the potential to guide aortic valve surgery and improve outcomes. Prior to aortic valve surgery, valvular pathology and annular measurements can be accurately examined for correct prosthesis sizing by TEE (Fig. 5). When aortic valve surgery is completed, thereby the TEE was used to evaluate the proper prosthesis seating and identify any regurgitation leakage around the prosthesis.

M-mode echocardiography remains useful in capturing the motion of the aortic valve; variations in motion patterns are often useful in differentiating severe from mild aortic stenosis. In the setting of a trileaflet aortic valve, aortic valve M-mode excursion of at least 12 mm is generally not consistent with severe aortic stenosis.

5.2.5. Congenital heart disease surgery[38,39]

Early neonatal repair of congenital heart diseases (CHD) has become possible recently, due to improvement of surgical techniques, cardiopulmonary bypass, and intraoperative TEE monitor. Intraoperative TEE is routinely used during cardiac surgery to improve the quality of surgical repair and potentially reduce the morbidity and mortality. We reported that intraoperative TEE reliably detected residual cardiac defects in 12 (5.6%) of 256 consecutive neonates and infants undergoing complex congenital heart surgery (Fig. 6-**1** and **2**).

(TGA). TGA is usually detected within the first hours to weeks of life. (A) 2D transesophageal echocardiography (TEE) at five-chamber view demonstrates that the PA arises directly from the left-sided posterior left ventricle and the Ao arises directly from the right-sided anterior right ventricle; (B) color Doppler shows abnormal crisscrossing of the Ao (anterior location) and PA (posterior location); (C) a newborn with an arterial switch operation putting the PA and Ao back into their correct places; and (D) the postoperative complication following arterial switch surgery with window between Ao and left pulmonary artery (LPA). LA = left atrium; LV = left ventricle; RA = right atrium; RV = right ventricle; SV = single ventricle.

Table 1
Congenital heart disease surgery and TEE monitored in 256 newborns and infants (1996.8–1998.8).

	No. of patients operated on	Operations revised no.
VSD	103	3
TOF	34	2
TGA/ASO	31	5
CAVSD	18	0
TAPVC	13	1
DORV	13	0
PA/IVS	9	0
HLHS	8	1
CoA/IAA	8	0
RAI/TAPVC	5	0
PAPVC	4	0
Truncus A.	3	1
ALCAPA	3	0
LPA sling/tracheal stenosis	3	0
RVOT tumor	1	0
	256	13 (5.1%)

The major CHDs are listed in Table 1 and include complete atrioventricular septal defect (CAVSD), coarctation of aorta (CoA), double outlet right ventricle (DORV), hypoplastic left heart syndrome (HLHS), partial anomalous pulmonary venous connection (PAPVC), total anomalous pulmonary venous connection (TAPVC), tetralogy of Fallot (TOF), ventricular septal defect (VSD), transposition of great arteries (TGA), anomalous left coronary arising from pulmonary artery (ALCAPA), truncus arteriosus (TA), and pulmonary atresia with intact ventricular septum (PA/IVS).

In addition, TEE is useful to visualize the precise anatomy of posterior cardiac structures, especially in pulmonary veins, while these structures were deemed to be difficult to be delineated by transthoracic echocardiography (TTE). Our previous study showed that seven (3 in supracardiac, 1 in intracardiac and 3 in infracardiac) of 31 infants with TAPVC had residual anastomotic site stenosis diagnosed by TEE following the primary repair, because Doppler ultrasound showed the presence of turbulent flow with a high mean peak flow velocity (>71 cm/second) at the anastomotic site.

Moreover, early detection of pulmonary venous obstruction by TEE provides the immediate management during heart[40] and lung transplantation.[41]

5.3. Catheter intervention

The rapidly expanding role of TEE in the management of heart disease includes guidance of interventional cardiac catheterization procedures and monitoring of results.

5.3.1. Patent ductus arteriosus[42]

Patent ductus arteriosus (PDA) is the second most common CHD. The ductus arteriosus (DA) is a fetal vascular connection between the main pulmonary artery and the aorta that diverts blood away from the pulmonary bed. After delivery, the DA undergoes active constriction and eventual obliteration. A PDA occurs when the DA fails to completely close postnatally. The first successful application of a PDA transcatheter closure technique suitable for use in infants and children was performed in 1977. Currently, transcatheter closure of PDA using the new Amplatzer ductal occluder is an easy and effective technique (Fig. 7). Moreover, it has even been shown to be safe in the presence of a wide PDA. It is particularly useful in symptomatic infants and small children with relatively large PDA. Two-dimensional imaging may provide important qualitative information regarding the hemodynamic significance of a PDA.

5.3.2. Patent foramen ovale and atrial septal defect[43–46]

Patent foramen ovale (PFO) is a flap-like opening between the atrial septa primum and secundum at the location of the fossa ovalis after the age of persistence. Most patients with isolated PFO are asymptomatic and receive no further treatment. However, paradoxical embolism in relation to PFO may cause transient ischemic attack or stroke. Percutaneous closure of the PFO is a widely used procedure in patients with paradoxical embolism (Fig. 8).

The use of TEE for guidance of transcatheter closure of secundum-type atrial septal defect (ASD) is increasingly

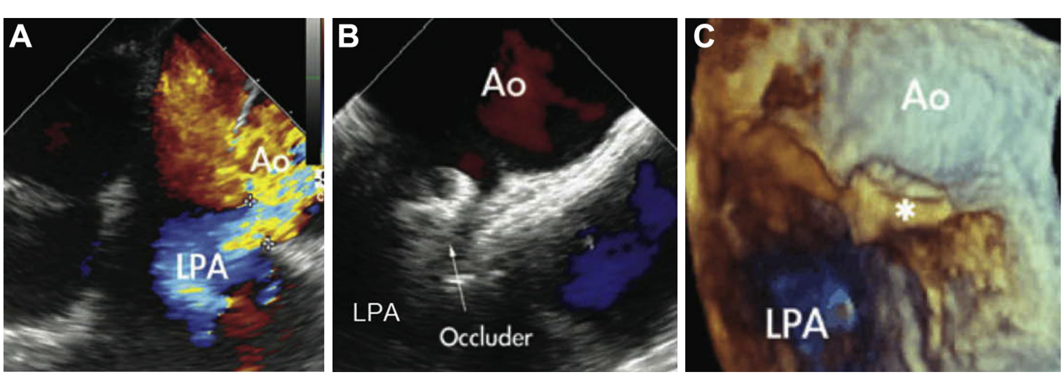

Fig. 7. (A) Two-dimensional (2D) transesophageal echocardiography (TEE) showed a large patent ductus arteriosus (PDA) (12-mm width) of the “window-like” type. Color Doppler flow image documented continuous left-to-right shunting from the aorta (Ao) into the left pulmonary artery (LPA); (B) transcatheter closure of PDA with the Amplatzer duct occlude (Occluder) in optimal position; and (C) real-time 3D TEE documenting the occluder (*) inside the PDA from the aortic perspective.

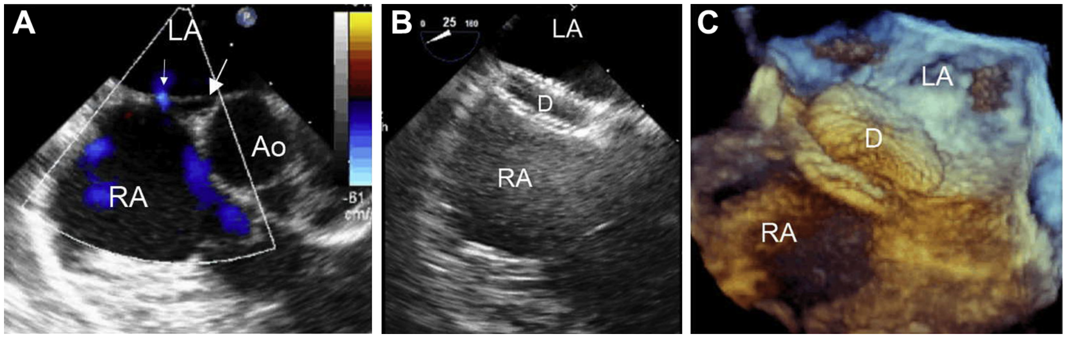

Fig. 8. (A) Two-dimensional (2D) transesophageal echocardiography (TEE) view demonstrated a patent foramen ovale (PFO) (large arrow) and an atrial septal defect (ASD) (small arrow); (B) a 24 mm Amplatzer PFO occluder device was implanted; and (C) 3D TEE demonstrated proper placement of the device with adequate coverage of all rims of the interatrial septum. Ao = aorta; D = Amplatzer PFO occluder device; LA = left atrium; RA = right atrium.

becoming a routine monitor. For transcatheter closure of an ASD, TEE provided visualization of the defect and its margins, to ascertain that the rims of the device were properly aligned and well seated on both sides of the interatrial septum. After release of the placed occluder device, TEE was used to visualize the normal anatomically closed defect, and color flow mapping was used to evaluate the presence and location of any residual interatrial shunting, possible obstruction to the systemic or pulmonary venous return, and impairment of atrioventricular valves.

3D TEE displays the defect as a dynamic ASD structure, the size and morphology of which changes with the cardiac cycle, and its maximal diameter can be better appreciated when the periphery of the defect is seen in *en-face* view. 3D TEE was used for patient selection and guidance to transcatheter closure of ASDs. One can visualize both atrial discs of the occluder device and their dynamic anatomic relation to the adjacent cardiac structures (Fig. 8).

TEE imaging not only assists in the positioning of devices and catheters, but reduces radiation exposure and contrast load in these patients and provides immediate and continuous assessment during cardiac catheterization procedures.

In 2008, 600 pediatric patients underwent transcatheter closure of ASD to evaluate the safety and feasibility of transcatheter closure of ASD. In addition, we assessed 124 consecutive patients with ASD (57 secundum-type, 67 with attenuated anterosuperior rim) closed with Amplatzer Septal occluder under TEE guidance. Our results show that the TEE was successful in depicting all four corners and corresponding edges of each Amplatzer disc, as well as the septal rims of all 57 secundum-type ASDs.

5.3.3. Ventricular septal defect[47]

Transcatheter ventricular septal defect (VSD) closure is a treatment option for isolated uncomplicated muscular VSDs, and for certain membranous VSDs. Device closure of muscular VSDs using an Amplatzer device has reported a very high rate of success (Fig. 9).[48] The success rate for percutaneous closure of membranous VSDs with Amplatzer devices is also high, but a VSD location remote from the tricuspid and aortic valves with an adequate rim have to be measured by the TEE. A complete arteriovenous wire loop from the aorta to the LV and VSD out into the RV was formed in order to guide the delivery sheath into the VSD from the RV.

5.3.4. Ruptured sinus of valsalva aneurysm[49]

Traditionally, surgical repair has been the mainstay of therapy. Percutaneous transcatheter closure of ruptured sinus of valsalva aneurysm provides a safe alternative strategy to surgery.

5.3.5. Percutaneous aortic balloon valvotomy

Calcific or degenerative aortic valve disease is considered the most common valvular lesion encountered among elderly patients. Critical AS is defined when the calculated effective

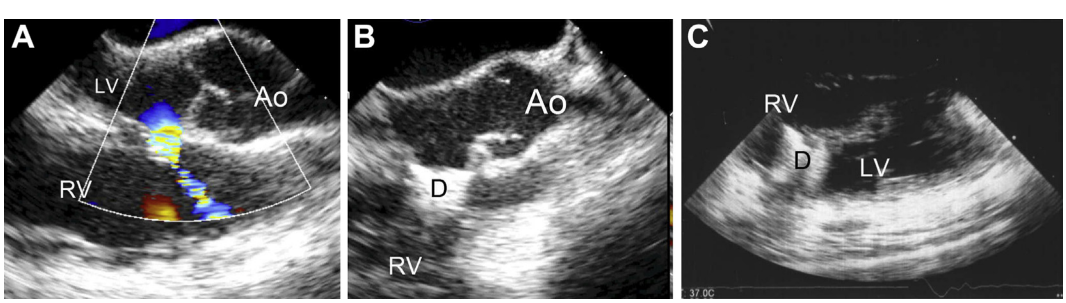

Fig. 9. (A) Two-dimensional (2D) transesophageal echocardiography (TEE) and color Doppler images of membranous ventricular septal defect (VSD); (B) the Amplatzer PDA occluder was implanted on the membranous VSD; and (C) Amplatzer muscular occluder was deployed on the muscular VSD. Ao = aorta; D = Amplatzer occluder device; LV = left ventricle; RV = right ventricle.

valve area is < 0.75 cm^2 or the Doppler aortic jet velocity is >5 m/second.

Percutaneous aortic balloon valvotomy is a procedure in which a balloon is placed across the stenotic aortic valve and inflated. This approach offers a means of symptomatic palliation and prevents performance of aortic valve replacement in serious comorbid patients, or as a bridge to transcatheter aortic valve implantation (TAVI).

5.3.6. TAVI[50]

Treatment of severe aortic valve stenosis in high-risk patients with percutaneous implantation of stent prosthesis has recently become feasible and is associated with a lower mortality rate.

Aortic stenosis is one of the most common valve pathologies found in elder adults. Patients with advanced age and multiple comorbidities, such as pulmonary, renal, or cerebrovascular dysfunctions and deconditioning, carry significant operative risks. Percutaneous transcatheter aortic valve implantation (Fig. 10) is an emerging and promising technique, and may lower the risk in this subset of patients. One of the most important elements of a successful TAVI is the proper placement and subsequent deployment of the device, which can be continuously monitored by the TEE. Incorrect placement may result in device embolization distally into the aorta, or proximally into the LV, causing hemodynamic instability.

Accurate measurement of the annulus diameter is crucial in determining the appropriate valve prosthesis size. TEE plays an important role in the evaluation of the eligibility of patients for percutaneous transfemoral or transapical aortic valve replacement. Correct sizing prevents device embolization and minimizes the degree of paravalvular leak. During the procedure, TEE assists in the advancement of guidewires and delivering system and subsequently the valve prosthesis. Complications such as aortic dissection, cardiac tamponade, and device malpositioning can readily be diagnosed by continuous TEE monitoring.

5.3.7. Transcatheter closure of mitral paravalvular leakage[51]

Paravalvular leaks are well-known complications seen following cardiac valve surgery. Paravalvular MR after MV replacement may lead to heart failure, hemolysis, and unilateral pulmonary edema. The use of percutaneous intervention techniques with an occluder device for mitral prosthesis paravalvular leak has become an attractive alternative to surgical repair. TEE is used to assess the location and severity of paravalvular MR before percutaneous closure and to guide the transapical puncture or retrograde approach (Fig. 11). When the occluder device is deployed, the use of TEE helps to confirm if it is seated on an appropriate position and the prosthetic valve functions. Moreover, the utilization of combined TEE and fluoroscopic guidance of interventional procedures can reduce the radiation exposure time.

In conclusion, in this article we describe the wide use of TEE in common and standard procedures for cardiac patients. The rapidly expanding role of TEE in the management of heart

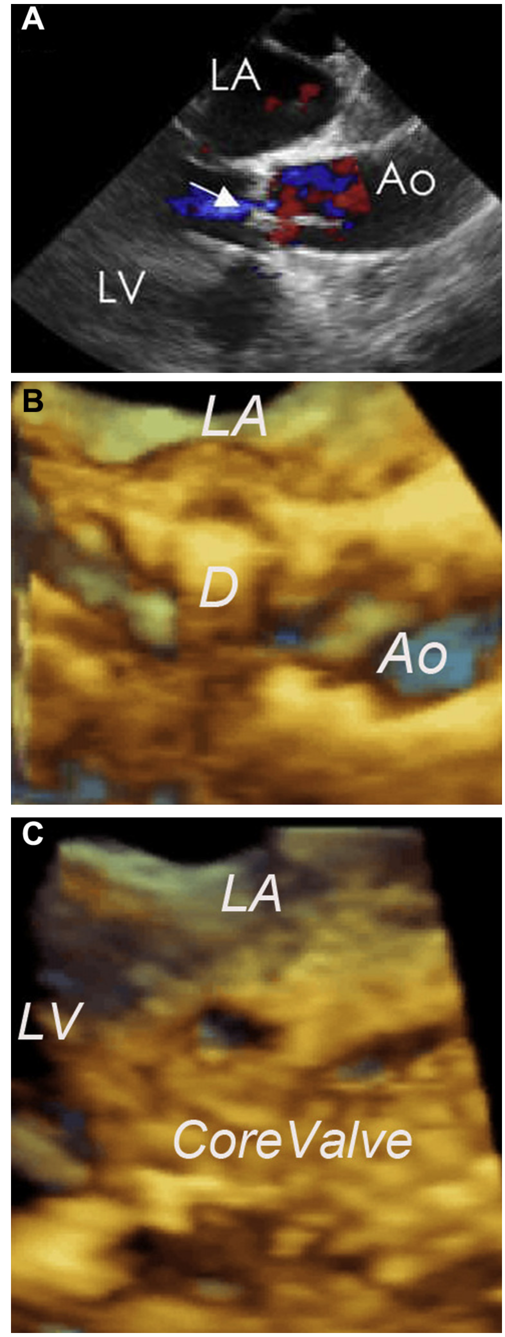

Fig. 10. (A) Long axis view of transesophageal echocardiography (TEE) shows the catheter (arrow) passing through the stenotic aortic valve; (B) long axis view of TEE confirms proper positioning of the balloon inflated (arrow); and (C) transcatheter approach completion TEE of implanted prosthetic aortic valve. Ao = aorta; LA = left atrium; LV = left ventricle.

disease includes acute ill patients for cardiac or non-cardiac surgery, emergency medicine and guidance of interventional cardiac catheterization procedures, and monitoring of results. Recently, real-time 3D TEE allowed for online assessment of cardiac structures and novel views of complex cardiac abnormalities in anatomy. Therefore, basic knowledge of cardiac anatomy and pathophysiology is of paramount important for a more complete understanding and wider use of TEE in clinical

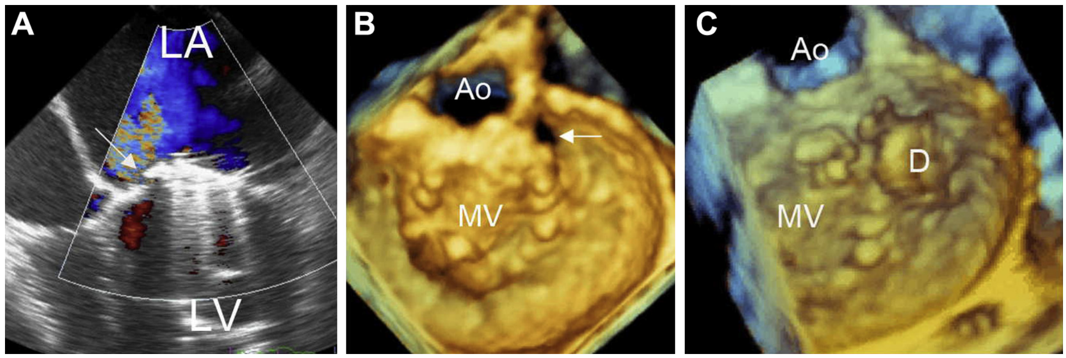

Fig. 11. Transapical closure of mitral paravalvular leak. (A) Apical four chamber view of two-dimensional (2D) transesophageal echocardiography (TEE) shows a paravalvular leak (arrow); (B) 3D TEE image of the mitral annulus and mechanical prosthesis en face from the left atrium in diastole. The paravalvular defect is located along the anteromedial border of the prosthesis ring at 3 o'clock (arrow); (C) 3D TEE image of the mitral annulus and mechanical prosthesis en face from the left atrium after introduction of a 10-mm Amplatzer muscular occluder device seated on the defect. Ao = aorta; D = Amplatzer occluder device; LA = left atrium; LV = left ventricle; MV = mitral valve.

management in patients with heart problems, to enhance the efficiency and safety of these procedures.

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