

Utility of perioperative transesophageal echocardiography

Few areas in cardiac anesthesia have developed as rapidly as the field of intraoperative echocardiography. Transesophageal echocardiography (TEE) in the operative room was initially applied for the assessment of global and regional left ventricular (LV) systolic function, but the clinical application of TEE has remarkably increased in the past two decades to include: (a) assessment of ventricular diastolic function, (b) assessment of mitral and aortic valve pathology and function, (c) detection of residual intracardiac defects and shunts, (d) detection of intracardiac air/clots, and (e) evaluation of ascending aorta.

Transesophageal Doppler was first described in 1971, and transesophageal M-mode in 1976. In 1980, Masayuki Matsumoto and Yasu Oka at Albert Einstein College of Medicine in the Bronx described the use of M-mode TEE for continuous monitoring of LV function in 21 patients during cardiac surgery. Later, Souquet, Schluter, and Hanrath introduced their phased array transducer system mounted on the end of a gastroscope that TEE became a practical reality. In the early 1980s, Peter Hanrath brought prototypes to the Mayo Clinic and the University of California in San Francisco (UCSF). A cardiology fellow from Hanrath's group in Germany, P. Kremer, joined Anesthesiologists Cahalan et al. and Michael Roizen at UCSF, and at the 1982 meeting of the ASA, they started the TEE "revolution" when they presented their results in monitoring cardiac and vascular surgery patients with this new TEE probe, describing its usefulness in assessing filling and function of the left ventricle, myocardial ischemia, and intracardiac air. In 1987, Cahalan et al. and Fiona Clements and Norbert deBruijn at Duke University wrote review articles on the use of TEE in anesthesiology. Indeed, the credit of obtaining the title of father of perioperative TEE goes to Cahalan et al. who pioneered the

use of TEE intraoperatively at the University of California. He introduced this technology to cardiologists, surgeons, and anesthesiologists. In 1986, Hewlett-Packard introduced color flow Doppler with TEE, and in 1987, deBruijn et al. at Duke University reviewed their early experience with this new technology. In that same year, pulsed wave Doppler was added to TEE, while in 1989, biplane probes first became available.

In India, the National and International Advisory Committees for TEE under IACTA have given the impetus to the TEE training program.

Perioperative echocardiography is widely used because it provides information that significantly influences clinical/surgical management and improves patient outcome in patients undergoing cardiac surgery. TEE provides new information on cardiac pathology in a significant number of patients and that the new information results in frequent management changes. In addition, there is increasing usage of echocardiography in critical care settings to aid diagnosis and management. Most physicians who care for cardiac surgical patients believe these benefits to be real monitory and have adopted the technique in their clinical practice to the full satisfaction of the entire team.

The intraoperative use of TEE is extremely useful in patients undergoing cardiac surgery

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contributing to the refinement of diagnosis and influencing the decision-making. There are several published reports of utility of TEE during the course of the preoperative period. Of the 587 interventions, TEE was the single most guiding factor in 17%. Interventions included fluid administration in 47% of the total therapeutic decisions. When compared to decisions made with the use of pulmonary artery catheter, clinically relevant decisions regarding fluid administration were done with TEE at least 4 times more frequently and reliably.^[1] In another study, which evaluated 5016 adult patients undergoing valve surgery and coronary artery bypass grafting (CABG) surgery, in 36%, the hemodynamic interventions were guided by the TEE, and in 23%, TEE was the sole guiding factor to initiate therapy.^[2] In yet another publication, TEE alter medical therapy in 53% of patients and in 30%, finding of TEE had an impact on the surgical decision.^[3] In a large series of 12,566 patients, 9% of surgical decisions were influenced by TEE. Based on current literature, it is evident that TEE is an invaluable diagnostic and monitoring tool in patients undergoing cardiac surgery.^[4]

MITRAL VALVE REPAIR

TEE examination before cardiopulmonary bypass (CPB) allows for the evaluation of the mechanism of valvular dysfunction and hence facilitates surgical planning.^[5] Post-CPB intraoperative TEE allows for the immediate assessment of the repair. This post-CPB evaluation should assess for residual mitral regurgitation (MR), systolic anterior motion of the leaflets, and restriction of leaflet opening indicating possible stenosis. It is critical that the TEE examination occurs under similar loading conditions to the patient's baseline status before surgery.

The AHA/ACC guidelines recommend intraoperative TEE for valve replacement surgery with a stentless xenograft, homograft, or autograft valve (Class I). TEE is important to detect paravalvular regurgitation or abnormal leaflet motion post valve implantation. In addition, for both mitral valve repair and replacement surgery, they are important to evaluate the LV for possible left circumflex coronary artery injury and the aortic valve for a suture-related injury to an aortic cusp.

TEE is the signal most important monitor influencing fluid administration; anti-ischemic therapy; and vasoconstrictor, inotrope, vasodilator, or antiarrhythmic administration. Major modifications of surgical

procedure based on TEE findings include graft revisions, "no-touch" technique due to ascending aorta atherosclerosis, or intraoperative balloon pump insertion.

Previously undetected aortic stenosis or mitral regurgitation during coronary artery bypass grafting

Elderly patients frequently require CABG and aortic valve replacement (AVR) secondary to aortic stenosis (AS). Occasionally, a patient may present for CABG with AS diagnosed during the intraoperative TEE examination. Indications for AVR are the same as if the patient was diagnosed preoperatively. If the AS is moderate or severe, AVR is indicated.

Undiagnosed MR in a patient undergoing CABG surgery is more controversial. A comprehensive examination of the mitral valve is necessary to determine the mechanism of the MR. Significant MR with a structural abnormality such as a prolapsed or flail segment warrants repair or replacement. Patients with moderate or mild MR during surgery are more difficult to evaluate due to the hemodynamic effects of anesthesia, which typically lessen the degree of regurgitation. It is, therefore, reasonable to perform MV repair in patients with newly diagnosed moderate MR detected on the intraoperative TEE examination.

With the growing interest in minimally invasive cardiac surgery, the role of TEE in these procedures has been evaluated. TEE facilitates the placement of intravascular catheters during port-access surgery, thereby avoiding the use of fluoroscopy. TEE is particularly useful for monitoring the placement and positioning of the endoaortic clamp and coronary sinus catheter that is used in these procedures.

Aortic atheromatous disease

The relationship between the severity of aortic atheromatous disease and postoperative cerebral dysfunction has been established previously. There is documented evidence of severe atheromatous disease in 10% of patients undergoing CABG. Protruding atheromas are significantly more common in patients over 60 years of age. To determine the optimal method to detect ascending aortic atheromas intraoperatively, manual palpation, TEE, and epiaortic scanning are used. Age, >70 years, and hypertension are significant risk factors for severe ascending aortic atheromas. Epiaortic scanning is found superior to both manual palpation and TEE. To advance the recognition of intraoperative epiaortic scanning, the American Society

of Echocardiography and Society of Cardiovascular Anesthesiologists jointly published guidelines for the performance of a comprehensive intraoperative epiaortic ultrasonographic examination in 2007.

Three-dimensional echocardiography

With the development of three-dimensional (3D) echocardiography, several investigators have explored its incremental value for the intraoperative detection of valvular lesions. In many instances, 3D-echocardiography provides complementary morphologic information that explained the mechanisms of abnormalities seen with conventional two-dimensional (2D) echocardiography. 3D echocardiography also allows direct visualization and planimetry of regurgitant orifice areas and measurement of regurgitant volumes.

Intraoperative dobutamine stress echocardiography has been utilized to detect inducible demand ischemia in patients with severe coronary artery disease and to predict functional changes after myocardial revascularization.

Echocardiography is an important diagnostic and monitoring bedside imaging modality which has transformed the care of critically ill patients. Many investigators have reiterated that echocardiography is of immense value in the critically ill patients; this modality of patient management is immediately available, portable, and importantly, relatively noninvasive and provides diagnosis fairly quickly without having to move the patient out of the Intensive Care Unit (ICU).

In patients with poor acoustic windows using the transthoracic approach, the only alternative is to use the transesophageal approach. The following views are particularly useful in the ICU setting with the TEE approach.

In patients with persistent or refractory hypoxemia, the presence of intracardiac shunt must be excluded by injecting agitated saline through the right side of the heart, for example, upper limb vein: intracardiac shunt results in saline contrast appearing in the left side of the heart instantaneously, whereas in case of an intrapulmonary shunt, for example, pulmonary arteriovenous malformation, the contrast appears on the left side after about 3–5 cardiac cycles.

LV global systolic performance is commonly expressed in terms of one or more of the following, all of which can

be determined by echocardiography by transthoracic echocardiogram (TTE) or TEE. The parameters are (i) fractional shortening (FS), (ii) fractional area change (FAC), (iii) ejection fraction (EF), and (iv) cardiac output.

Fractional shortening

FS is determined by the formula: $LVIDd - LVIDs/LVIDd \times 100$ where, IDs refers to the internal diameter in systole and IDd refers to the internal diameter in diastole, using TEE. It is best estimated using the transgastric mid-papillary short-axis. FS is heavily afterload dependent and slightly preload dependent.

FAC is a relatively simple parameter to determine that is obtained from the transgastric mid-papillary view. FAC is the relation between LV diastolic area to the systolic area obtained from the following equation: $FAC\% = \text{end diastolic area} - \text{end systolic area}/\text{end diastolic area} \times 100$.

Ejection fraction is calculated using the equation: $EDV - ESV/EDV \times 100$, where EDV refers to end-diastolic volume and ESV refers to end-systolic volume. However, please note that all geometric methods make assumptions on the shape of ventricle and presence of wall motion abnormality makes the determination of EF untenable.

ESTIMATION OF CARDIAC OUTPUT

Flow across a fixed orifice is the product of the cross-sectional area (CSA) and the velocity of flow through the orifice. The cardiovascular system is pulsatile and hence the velocity of instantaneous blood flow varies. The integration of the instantaneous flow rate over the entire flow period through a given orifice is called the velocity-time integral (VTI). Stroke volume (SV) is derived as a product of CSA and VTI as shown below. Cardiac output, in turn, is the product of the SV and the heart rate. The preferred site of measurement of SV and cardiac output is the LV outflow tract.

DIAGNOSIS OF INFECTIVE ENDOCARDITIS

Echocardiography is necessary for the diagnosis and management of patients suffering from infective endocarditis (IE). The two essential components of echocardiographic features of IE are (i) oscillating intracardiac mass or vegetation, (ii) annular abscess, dehiscence of prosthetic valve, or acute valvular regurgitation.

DETECTION OF MYOCARDIAL ISCHEMIA

Recognition and identification of regional wall motion abnormality can be readily achieved by 2D echocardiography in the ICU setting. Serial echocardiography is useful in monitoring the success of reperfusion therapy and extent of myocardial viability.

TEE is an extremely useful modality for the diagnosis and classification of thoracic aortic pathology, namely, aneurysm, dissection, and atheromatous lesion. A thoracic aortic aneurysm is a permanent localized dilatation of thoracic aorta that has at least a 50% diameter increase involving all the three layers of the vessel wall. Less than 150% of normal localized dilatation of the thoracic aorta is termed "ectasia." Annuloaortic ectasia is defined as isolated dilatation of the ascending aorta, aortic root, and aortic valve annulus. A false aneurysm or a pseudoaneurysm is a localized dilation of the aorta that does not contain all three layers of the vessel wall; instead, a false aneurysm consists of connective tissue and clot.

TEE is particularly useful in diagnosis of an aortic dissection with a complete picture of origin/ location of dissection flap, involvement of coronary ostia with an associated risk of myocardial ischemia, degree of aortic insufficiency, and pericardial effusion.

DIAGNOSIS OF PERICARDIAL TAMPONADE

Quick and rapid accumulation of pericardial fluid in the closed pericardial cavity can precipitate hemodynamic instability and cardiovascular collapse.

The 2D echocardiography either using TTE or TEE is useful to provide supportive evidence of acute pulmonary embolism. McConnel et al. demonstrated that patients with acute pulmonary thromboembolism have a distinct regional pattern of right ventricular (RV)

dysfunction with akinesis of mid-free wall but preserved contractility of the RV apex.

Hemodynamic instability associated with hypotension in the ICA is a class I indication for performing TEE. The advantage of TEE is that it is provident better acoustic windows than that with TTE in almost all mechanically ventilated patients. It has been demonstrated that TEE leads to a change in management in more than 50% of ICU patients when performed for hemodynamic instability. TEE is especially of proven value for the assessment of suspected IE and diagnosis of aortic dissection.

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