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Adult Perioperative Echocardiography: Anatomy, Mechanisms and Effective Communication

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ABSTRACT

Intra-operative transesophageal echocardiography (TEE) is a mature imaging technique which represents the premier surgical quality control instrument in the contemporary operating room. In adult cardiac surgery, management of valvular heart disease and related structural cardiac abnormalities derive the most benefit from perioperative echocardiography which includes pre-operative transthoracic echocardiography, intra-operative TEE and post-surgical echocardiographic surveillance. This review discusses the theoretical background upon which these imaging techniques are built-on, and offers a practical state-of-the-art guide on their application, emphasizing the importance of anatomic relationships, mechanisms of dysfunction and effective communication with our surgeons.

Background and critical principles

The concept of transesophageal echocardiography (TEE) emerged in 1976[1] as a solution to cardiac imaging in patients with poor transthoracic echocardiogram (TTE) acoustic windows. However Frazin et al.[1] could not have predicted that TEE, by virtue of not intruding into the surgical sterile field, would allow real-time cardiac imaging during cardiac surgery and thus become the premier surgical quality-control instrument for heart surgeons. TEE has evolved to provide real-time 2 and 3-dimensional imaging of heart and valve structures as well as valvular hemodynamic performance with Doppler spectral and color-flow imaging.

Despite no randomized data on patient-important outcomes supporting its routine use,[2] intra-operative TEE (IOTEE) has become widely utilized in cardiac surgery theaters worldwide. Studies totaling over 25,000 patients demonstrate a complication rate ≤ 0.2% and mortality < 0.1% for TEE/IOTEE,[2] a crucial safety concept upon which a body of indirect evidence supporting the use of IOTEE has been constructed. Certainly, improvement in patient-important outcomes can be inferred from the results of nonrandomized trials of test accuracy[3] (i.e., IOTEE versus direct surgical observation for cardiac anatomy/valvular dysfunction mechanisms, and IOTEE versus TTE for hemodynamic valvular assessment), provided that effective treatment for the abnormalities detected by that test is available (i.e., additional pump runs to correct residual abnormalities identified by IOTEE) and that test-related adverse effects are minimal.[2] The above conditions are given for IOTEE.[2] Furthermore, the use of IOTEE results in non-planned surgical alterations at the pre-cardiopulmonary bypass (Pre-CPB) and post-cardiopulmonary bypass (post-CPB) junctures, where the post-CPB setting is critical since it offers the opportunity of prompt recognition of abnormalities which can be treated immediately, preventing future re-do surgeries, as well as patient morbidity and mortality. Thus, the timely presence of the echocardiographer during the

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Abbreviations and Acronyms

AR = aortic regurgitation

CPB = cardiopulmonary bypass

ERO = effective regurgitant orifice

HCM = hypertrophic cardiomyopathy

IMR = ischemic mitral regurgitation

IOTEE = intra-operative transthoracic echocardiogram

LV = left ventricle or left ventricular

LVOT = left ventricular outflow tract

MR = mitral regurgitation

PISA = proximal isovelocity surface area

SAM = systolic anterior motion of the mitral valve apparatus

TEE = transesophageal echocardiogram

TR = tricuspid regurgitation

TTE = transthoracic echocardiogram

VHD = valvular heart disease

transition off of CBP for goal-directed assessment of surgical results under appropriate hemodynamic conditions, followed by effective communication of detected abnormalities and their mechanisms to the surgeon, is critical (Table 1). Common pre-CPB surgical-altering IOTEE findings include patent foramen ovale, unsuspected mitral regurgitation (MR), aortic atheroma, endocarditis complications, intracardiac thrombus and left ventricular outflow tract (LVOT) obstruction,[2,4,5] whereas the majority of post-CPB surgical-altering findings are related to less-than-satisfactory valvular intervention results, and less commonly to graft revisions and other rare complications (i.e., ventricular septal defect, iatrogenic aortic dissection). Hence, the impact of post-CPB IOTEE is the greatest for valvular heart disease (VHD)[2,6–9] (Table 2). Indeed, significant VHD affects 13% of patients ≥ 75 years,[10] primarily driven by MR and aortic stenosis (AS). This has led to a recent increase in surgical valvular procedures, especially aortic and mitral; accompanied by improved surgical survival trends. Echocardiography aids the surgeon in tailoring the surgical approach to the specific mechanism of valve dysfunction, identification of additional abnormalities that may warrant intervention, and timely intraoperative evaluation of surgical results allowing immediate correction of less than satisfactory results. Patients with moderate residual valve dysfunction have more postoperative complications and higher mortality compared to those with a satisfactory valve surgery result,[11] highlighting the importance of post-CPB identification and correction of more than mild valve dysfunction before the patient leaves the surgical suite. For this process to be meaningful, the patient who reaches the operating room must have hemodynamically severe VHD established pre-surgically, thus the importance of perioperative TTE (Table 1).

Landmark practice guidelines for the application of IO TEE have been developed[12–15] and valvular repair and replacement are considered primary indications for IO TEE monitoring. Other primary indications for IO TEE include conditions commonly associated with VHD: hypertrophic cardiomyopathy (septal myectomy), ascending aortic disease, and congenital heart disease.[14] This review will not discuss the use of IOTEE in congenital heart disease.

Table 1 – Critical principles in perioperative VHD echocardiography.

Importance of Perioperative TTE

- Assess hemodynamic significance of valve lesions by TTE: the only precondition for a perfect valve repair or replacement is that the native valvular lesion is indeed severe
- Assess aortic stenosis peak velocity and mean gradient from multiple windows
- Assess right ventricular function
- Assess TR severity (color scale ≥ 60 cm/s) and tricuspid annular dimension
- Assess MR and AR severity (color scale ≥ 60 cm/s) and repairability
- Evaluate mitral annular calcification severity (critical for mitral repair and replacement)
- Evaluate LVOT obstruction

IOTEE Pre-CPB Goals

- Corroborate valvular dysfunction severity and refine mechanisms and approaches for effective communication to the surgeon
- Assess right and left ventricular systolic function
- Assess severity of AR for cardioplegia planning
- Search for unsuspected conditions i.e., thrombus, papilloma
- Exclude ascending aorta atheroma that may affect cannulation
- Rule out interatrial communication

IOTEE Post-CPB Goals

- Timely presence of echocardiographer in operating room
- Assist surgeon in de-airing procedures
- Reassess left and right ventricular systolic function
- Anatomic and hemodynamic evaluation of valvular procedure result under appropriate hemodynamic conditions of heart rate, blood pressure and intra-cardiac volume
- Effective communication of residual severity of valvular dysfunction, anatomy and mechanism of dysfunction
- Rule out ascending aorta hematoma or dissection

Importance of Post-Operative TTE

- Assessment of valvular function, left-right ventricular function, and presence of pericardial collections (i.e., hematomas) in the unstable patient during post-operative hospital stay
- Pre-discharge TTE serves as a baseline (“finger print”) for future comparison, especially for valvular function (native and prosthetic)

Table 2 – IOTEE impact according to surgical setting.

Surgical Setting	Valvular Heart Disease [a]	Adult Cardiac Surgery [b]	CABG [c]
Post-CPB IOTTE impact	4%	2.2–2.5%	0.8–1.0%

[a] Average of 8 major IOTEE valvular studies,[2] driven by additional pump runs for aortic and/or mitral repair surgeries.
[b] Does not include adult congenital heart disease surgery, based on 2 large contemporary studies.[6,7]
[c] Studies or sub-studies including primarily coronary artery bypass surgery (CABG).[6,8,9]