Journal of Anesthesia & Clinical Research
Duque and Machado, J Anesth Clin Res 2016, 7:6
DOI: 10.4172/2155-6148.1000634
Review Article Open Access

Intraoperative Transesophageal Echocardiography: Review and Evolution

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Received date: May 07, 2016; **Accepted date:** June 20, 2016; **Published date:** June 25, 2016

Abstract

Background: Presently, transesophageal echocardiography (TEE) is routinely used in adult cardiac surgery with increased frequency as well as in perioperative hemodynamic monitoring during noncardiac surgeries.

Objectives: The aim of this analysis was to understand the evolution of the use of intraoperative TEE (iTEE) both in cardiac and noncardiac surgeries showing popular and challenging approaches in its use, and as a secondary goal, to understand the patterns to achieve competency.

Methods: A literature review was carried out identifying relevant clinical studies published in last six years using the keywords listed below.

Results: The quick acquisition of cardiac anatomy and function data give iTEE an importance in cardiac procedures that is undeniable, permitting refined diagnosis, detect unsuspected pathology, adjust both anesthetic and surgical plans and evaluate immediate surgical outcomes. Although, its use is less established in noncardiac surgery, the latest guidelines give an increasingly role for TEE in monitoring patients in high risk surgeries or in patients with several comorbidities that can compromise the hemodynamic status even in lower risk surgeries. iTEE is a multifaceted technical expertise and demonstration of competence is usually accomplished by successful conclusion of a training program and passing an examination. Restrictive factors to incorporating TEE proficiency into all anesthesia training include limited available equipment and trained operators.

Conclusions: iTEE should be used as an auxiliary tool to have more comprehensive understanding of the patient's cardiovascular physiology and manage a most adequate anesthetic approach and surgical intervention. Meanwhile, it is advisable to have large systematic studies supporting its powerful value in both cardiac and noncardiac surgeries. Suitably, it is desirable an international adoption of TEE basic skills within anesthesia practice. Education is the most influential instrument to contribute in shifting the anesthesiology community's standpoint of TEE use in daily clinical practice.

Keywords: Transesophageal echocardiography; Intraoperative; Cardiac surgery; Noncardiac surgery

Introduction

Cardiovascular monitoring during a surgical procedure can be a challenge for the anesthesiologist, especially if the patient has high probability of hemodynamic instability.

The introduction of transesophageal echocardiography (TEE) in the operating room (OR) represents a development of the management of such patients, even in those who were not at risk, but suffered from a consequence or complication through the procedure. This technique allows a direct and fast image of the heart and great vessels by using high frequency ultrasound probes that improved the special resolution due to the proximity between the transducer and the heart.

Invasive blood pressure monitoring is essential in intraoperative management, but the accuracy of peripheral readings in comparison to central measurements has been questioned. The role of this intraoperative management tool became difficult to define. It's now part of the decision-making process, providing determinant information; TEE can change the surgical procedure, anesthetic plan, confirm a suspected diagnosis, assist in positioning of intravascular devices and may extend far for additional follow-up. Intraprocedural TEE can be divided in surgical-based procedure and catheter-based procedure [1-4].

However, its use during non-cardiac surgeries is less established, the latest guidelines of the American Society of Anesthesiologists (ASA) and Society of Cardiovascular Anesthesiologists (SCA) agreed that TEE should be used in noncardiac surgery when patients have known or suspected cardiovascular pathology that might result in hemodynamic, pulmonary or neurologic compromise, and if experts and equipment available in conditions of unexplained life-threatening circulatory instability persists despite corrective therapy [1,3,5]. Yet, the use of iTEE in noncardiac surgery won its own role here, since it is now routinely an assessment tool in monitoring patients in high instable risk surgeries.

Objectives

The aim of this review is understand the evolution of the use of intraoperative TEE both in cardiac and noncardiac surgeries and as a secondary goal to understand the patterns to achieve competency.

Material and Methods

A literature review was carried out identifying relevant clinical studies published after 2010 covering a 6-year period from 2010 to 2016. PubMed and Google scholar were used to identify suitable publication for inclusion. Transesophageal echocardiography, transesophageal echocardiography in cardiac surgery and transesophageal echocardiography in noncardiac surgery were the used keywords.

Results

In 2014, ASA and SCA published the most recent guidelines to perform a comprehensive TEE examination; the document does not address basic perioperative TEE, which is a noncomprehensive examination for intraoperative monitoring and evaluation of hemodynamic instability. The last mentioned are especially for intraoperative imaging and do not included some views important to other applications of TEE. Another guidelines for practice developed by ASE and SCA in 2010 provide the physician support in determining the appropriate application of iTEE in order to improve the outcomes based on the strength of supporting evidence [1,6].

The main indications to use iTEE are recommended for cardiac and thoracic aortic surgery, catheter-based intracardiac procedures and noncardiac surgery [6]. These guidelines combined opinions from experts, ASA members and literature review; it is clear that literature in the past 5 years developed in a mode that iTEE is increasingly expended for several other indications with evidence-based. Thus, the authors of this work suggest a new paper addressing updated practice guidelines.

Discussion

Cardiac surgery

TEE not only is a clinical beneficial modality to influence anesthetic and surgical decision-making in cardiac surgery but also a cost-effective one. Canty et al. found that TEE can predict left ventricular distention, which is common in these surgeries [7]. In addition, the assessment and management of LV diastolic diameter and area can be used to diagnose hypovolemia and monitor fluid therapy.

Perhaps one of the most valuable contributors of 3-dimension (3D) TEE in the OR is the assessment of the left ventricle (LV). The accuracy of LV volumes and function attained by TEE assemble those acquired by cardiac magnetic resonance image (cMRI). As technology continues to grow, LV volumes and ejection fraction became easy and quick values analysed during surgery and early detection of wall motion abnormalities, helped evaluating patient cardiac function status intraoperatively [1,8].

Left ventricle (LV) mass is a commonly used predictor of cardiovascular disease morbidity and mortality. During cardiac surgery, LV mass can be calculated by multiplying the LV myocardium volume by its weight through iTEE, permitting diagnose LV pathology, such hypertrophic cardiomyopathy [8]. This is remarkably useful in non-elective surgeries where cardiac abnormalities are found. In addition, the assessment and management of LV diastolic diameter and area can be used to diagnose hypovolemia and monitor fluid therapy.

Evaluation of RV function should be routinely performed since it has a very useful significance predicting morbidity and mortality in cardiac surgical patients, particularly in hypotension [1]. While gold standards for RV function are cMRI and radionucleotide ventriculography, TEE seems to be the most feasible tool to its evaluation in the OR. 3D technology permits complete assessment of RV volumes, anatomy, geometry and ejection fraction. With this capability, it is expected that RV imaging and function become part of a comprehensive TEE examination, emphasizing the influence of this evaluation [8,9]. Although, iTEE is not the gold standard for pulmonary embolism (PE), echocardiographic findings consistent with acute PE are RV dysfunction an atypical wall motion abnormalities of RV free wall [1].

Real time (RT) 3D TEE can accurately assess location, attachment and size of intracardiac masses as atrial and ventricular septal defects, simplifying surgical planning [10-12]. Myxomas are the most common cardiac tumors and may arise in any of the four cardiac chambers, usually in the left atrium (LA). Observing the relation between LA and mitral valve (MV) it is possible to predict dysfunction when tumors are large enough or their location covers MV area [13]. Yamagushi and Koide reported a case in which a masked mitral regurgitation was only detected after tumor resection; nevertheless it permitted support decision-making for appropriate MV procedure [14]. The authors reinforced the idea that TEE should be used continually to evaluate the possible presence of MV dysfunction before and after tumor resection. In addition, Dharmalingam and Sahajanandan demonstrated a shifting in surgical plan in a man with right atrial myxoma, highlighting the importance of TEE characterizing cardiac masses [15]. TEE performed intraoperatively gave specific information's about the attachment and extent of the myxoma. Among valvular masses, the most known are infective endocarditis vegetations', in which TEE is recommended for surgical cases, refining surgical manage [16,17].

Mitral valve surgery

Surgical repair of the mitral valve is being progressively implemented to treat severe mitral regurgitation, which is an excellent treatment option with low-risk and high durability. One of the strongest indications for iTEE is evaluation MV during repair or replacement. The MV apparatus, function and the pathological segments are evaluated under general anesthesia, as well as other risk factors that can be assessed for surgical repair and correct placement of the cannulas used for CPB in minimally MV repair surgery [18,19]. When a nonsystemic approach is used to assess mitral valve morphology, like in perioperative period, there is good agreement between TEE and surgical findings [20].

Considering postoperative evaluation of MV repair or replacement, 3D TEE has been shown to simplify visualization of the entire structure of the new artificial valve and its function. Qualitative imaging of 3D TEE is more suitable to visualize anatomy and locating pathologies whereas quantitative analysis of 2-dimension (2D) TEE is more accurate for measurements and quantifying severity. In addition, color Doppler 3D TEE can show the right location of paravalvular MR, helpful for transcatheter closure of leaks with immediate surgical correction. It is necessary to exclude mitral stenosis, and assess ventricular function [8,9,18,19,21-25]. Even some echocardiographic variables are recently identified as independent risk predictors of procedural failure [26].

As new minimally invasive and even off-pump techniques for MV repair/replacement become well known, the role of TEE turns out to be essential for monitoring these less invasive approaches since simplifies the surgery, improves outcomes and is highly rewarding [18].

Aortic valve surgery

For several years, TEE is used to see immediate results and, if necessary, for reintervention to improve the adequacy of prosthetic valve in percutaneous valve implantation [27]. Besides that, iTEE is routinely performed after cardiopulmonary bypass (CPB) to evaluate the adequacy of aortic valve (AoV) repair in adult population. AoV repair is an alternative approach to valve replacement with the advantages of eliminating the need of long-term anticoagulation and prosthetic-related complications such thromboembolic events and endocarditis. However, during aortic valve replacement, TEE allows sizing the annulus and confirming satisfactory function after implantation.

A pre-repair TEE usually focuses on anatomy and function of the AoV, planning the viability of the AoV procedure. An immediate post-repair evaluation provides important information about the quality of the surgical repair (coaptation's level relative to the annulus and length of cusp coaptation) and mechanisms of any residual aortic insufficiency (AI). In some cases, the amendment of contributing lesions should be done concurrently to guarantee a suitable result. If the repair is considered inadequate, an echographic image of the valve is absolutely critical and will guide the surgeon to correct the causes of residual AI during re-evaluation, or if the repair is no longer reasonable, and the decision to replace the valve may be made [28-30].

Coronary surgery

The utility of TEE in revascularization surgery should be considered to refine preoperative diagnosis, detect new unsuspected pathology, manage both anaesthetic and surgical plans appropriately and evaluate surgical results [6]. Evidences show that iTEE is the most sensitive method in the diagnosis of myocardial ischemia, detecting segmental wall abnormalities less than a minute after inadequate myocardial perfusion, preventing an unsuccessful revascularization. In addition, it can also detect incidental cardiac conditions that may require surgical intervention. The detection of these alterations modifies the therapeutic conduct [31,32].

In patients undergoing coronary artery bypass grafting, atherosclerotic disease can lead to perioperative complications. Several studies showed that the severity of the atheroma found in iTEE is strongly related to stroke and other negative outcomes after coronary artery surgery [33]. Nowadays, literature is more oriented in preoperative evaluation of patients, so their risk factors can be promptly added to surgical and anaesthetic planning.

Even in something as rare as coronary aneurisms, TEE could detect intraoperatively dilations of these vessels and equally helped to approach complications during these techniques [34,35].

Aortic surgery

iTEE should be used routinely in thoracic aortic surgery [6]. Currently, TEE is considered the first-line exam in the diagnosis of thoracic aortic dissection (AD) in hemodynamic instable patients; true and false lumens can be difficult to distinguish and so the presence of blood flow in true lumen and slow or absence of flow in false lumen can be perceived through TEE colour Doppler. It has proven specifically valuable for choosing the landing site for the proximal stent by clarifying areas of atheroma and calcification that would otherwise not be perceived by angiography and could interfere with stent adhesion. iTEE is highly useful during endovascular treatment in complicated descending AD. It allows identify true and false lumens by guide wiring entrance, false lumen thrombosis and anterograde and retrograde flows, evaluate correct stent-graft positioning, possible leaks and small re-entry tears, all critical evidence with prognostic implications [6,28,36-38]. Orihashi et al. in a recent case report showed that TEE besides being useful in stent guidance during open stent graft procedure, it also was a valuable tool for diagnosing a stent migration occurred intraoperatively [39]. It looks intuitive to think of TEE as an accurate check-up tool in operative period.

Although recent guidelines recommend TEE for any aortic surgery involving the ascending, arch, or proximal descending aorta, it has not been used universally. Little is known about the impact of TEE in the management of AD. In literature, some studies have been performed that showed its role even in abdominal aorta. In abdominal aneurysm surgery, acute AD is an atypical and fatal complication that can develop during open repair of an abdominal aortic aneurysm. Kainuma et al. reported a case describing the usefulness of TEE for the diagnosis and operative decision-making during the management of an acute AD [40]. TEE revealed the existence and extension of the dissection, presence of AR and absence of myocardium and coronary involvement as well as pericardial effusion. Thorsgard et al., in a retrospective study showed that TEE data led to a change in planned surgery in 39% of the patients in acute type-A AD. According to the previous literature, this number is a little higher (6-30%) but it is specific for this surgery and it can be as high as in other emergent surgery procedures, entirely distinctive of the complete data that is required in an elective surgery patient [41].

Pediatric and congenital heart disease surgery

As in adult population, iTEE in infants who undergo cardiac surgery is a valuable tool that confirms diagnosis by other imaging devices and can identify additional pathological disorders. Before surgical correction, TEE confirms diagnosis and after surgical repair assesses correct fix and detects remaining lesions. A recent study showed that in almost 6,5% of the patients undergoing surgery for congenital heart disease (CHD), iTEE changed surgical plan and allowed immediately repair of surgical abnormalities [42,43].

TEE is used in several different surgical procedures in CHD such atrial septal defect (ASD), ventricular septal defect (VSD), valve replacement, atrioventricular canal, combined ASD and VSD or combined VSD and pulmonary stenosis, valve reconstruction, subaortic stenosis resection, reoperation and neo-natal surgery, Fontan procedure, Tetralogy of Fallot (TF), Ebstein anomaly and even in extracardiac procedures [42].

In pediatric population, TEE has adverse effects too. Compression of the airway leading to desaturation and hemodynamic instability are the most common side effects in younger patients and trauma during insertion and extubation, especially in neonates. Technological advances permitted the accessibility of pediatric probes in surgeries for CHD in children. The use of these probes is limited in small infants weighing less than 5 kg, but a weight-based algorithm can help determine neonates at risk for iTEE probe insertion failure. It has been suggested that smaller TEE probes might benefit this patient population, once some heart diseases need intervention right after birth. Small probes with 5mm could be used in neonates with less than 2.5 kg [42,44]. Zyblewski et al. established that the use of new multiplane micro-TEE provided high quality, useful diagnostic images without hemodynamic or ventilation compromise in small infants undergoing cardiac operations [45]. The innovation is especially important with the growing trend towards complete repair of complex structural heart disease in toddlers [44].

In a high-risk surgery as TF correction, iTEE revolutionized cardiac evaluation during the procedure, assessing primary anomalies, immediate surgical revision, residual defects and hemodynamic monitoring. TEE improved clinical outcomes in these patients [46].

Although well described in adult population, TEE predictors of aortic regurgitation (AR) after AoV surgery may not be appropriate in pediatric population, given the disparities in underlying diseases. Stern et al. studied which intraoperative post-CPB TEE variables could predict higher risk of early reoperation for recurrent AR in children with congenital aortic valve disease [29]. They found that higher risk was present with coaptation asymmetry, measured through the difference in percentage between short-axis coaptation lengths. This parameter is a simple calculation in standard TEE view, strengthening the value of TEE in decision-making process. The information could lead to a return to bypass to improve coaptation symmetry and so preventing reintervention in these children. Still, since this was a small group study, a larger sample size studies could corroborate these finds.

In congenital mitral valve disease, Song et al. demonstrated the utility of iTEE in MV replacement, which diagnosed an incorrectly placed prosthetic valve permitting proper implantation after reinitiating CPB [47].

Transesophageal echocardiography plays also a crucial role in performing minimally invasive surgical closure of cardiac defects, showing more accuracy about real dimension of the defect than transthoracic echocardiography [48].

Non cardiac surgery

The questions faced in the OR during a noncardiac surgery are rather distinctive. TEE can be an important tool for patients with significant comorbidities or if hemodynamic instability is anticipated or occurs intraoperatively [49].

Hemodynamic instability and quick changes in volume are serious complications. The impact of direct visualization of cardiac structures has the potential to provide quickly important information on cardiovascular function relevant to hemodynamic management. In complex noncardiac procedures such has liver transplantation, due to surgical manipulation or blood loss, the probability of hemodynamic instability is high and so iTEE can add important information to patients managing.

Moreover, hypotension and arrhythmias are frequently associated with hemodynamic instability. The first one can be due to cardiac failure, hypovolemia or reduced peripheral resistance (RPR). Even in acute blood loss, RPR can be existent along with signs of hypovolemia. Consequently, evaluations of cardiac output and cardiac preload are important factors in intraoperative examining. Many of these variables demonstrate good correlation when compared with more invasive techniques, even in the case of detecting acute hemodynamic changes; TEE is superior to pulmonary artery catheter [37].

To show an original and astute use of this device in noncardiac surgery, in 2014 it was described a rare case report of which an external masse (transplanted liver) caused a cardiac compression resulting in several episodes of supraventricular tachycardia immediately after the transplant. This symptomatic myocardial compression by the liver was guided and confirmed via RT-TEE imaging with a successful resolution [50]. Even in obstetric surgery, Cho et al. reported a rare case of abrupt hemodynamic instability in a woman during a vaginal hysterectomy, iTEE was performed and a right atrium thrombus was identified [51].

In the case of neurosurgery, the sitting position (SP) has been an important approach to improve surgical field, however the risks are not negligible. While TEE is the most sensitive modality for detecting air in the right atrium, sitting position is relatively safe without TEE and TEE does not change outcomes. Additionally TEE is cumbersome given where the patient and surgeon are positioned [1,52].

Liver transplantation

Patients undergoing orthotopic liver transplantation (LT) may present cardiac dysfunction from cirrhotic cardiomyopathy or pre-existing coronary artery disease. In addition, patients are at risk of hemodynamic instability due to several causes, blood loss, obstructed inferior vena cava flow, increased workload, embolization, and reduced systemic vascular resistance. These circumstances can be assessed by TEE and make a difference in patient's outcome, creating an opportunity to identify early and prevent future complications [49]. Concerns about these conditions may refrain anesthesiologists from practice intraoperative TEE. Nevertheless, in patients with pulmonary hypertension, RV dysfunction can be a complication during surgery and it is recommended to perform a basic iTEE, allowing quick determination of cardiac status and therapeutic attitudes [1]. Recent guidelines listed esophageal varicose veins, coagulopathy, thrombocytopenia and recent upper gastrointestinal bleeding as contraindications to use TEE, however literature considered that it is relatively safe despite the risk of varicose veins haemorrhage [53]. A recent retrospective study about iTEE in orthotopic LT showed that it was relatively safe procedure in patients with documented esophagogastric varicose veins and coagulopathy, with a low incidence of major hemorrhagic complications (0,43%) [54]. The grade of the varicose veins seems to be related to the probability of bleeding, although grade IV is an absolute contraindication, in grades I and II TEE has been performed safely [55,56]. In addition, a contemporary retrospective study in University of California, population of 433 patients with model for end-stage liver disease (MELD) score 25 or higher demonstrated that iTEE was not associated with major gastroesophageal and hemorrhagic complications during LT [57].

Nevertheless, there are some methods that decrease the risk of varicose veins rupture during iTEE in liver transplantation, such as experienced operators with strict vigilance, gastroenterology consultant and correction of coagulopathy before the TEE procedure [1,6,58].

Considering the great dimension of this surgery, hemodynamic patterns are very important to monitor, and TEE has shown accuracy to determine essential changes, such stroke and end diastolic volumes, wall abnormalities, air embolism, shunts, effusions and valvular pathologies. Influence of TEE on fluid therapy during liver transplantation is also well documented in literature, up to 50% in some series [59]. Although transgastric views are limited, the short axis view gives a better assess to the circumference of the left ventricle by overpassing posterior retraction of the stomach [60].

The less invasive option to monitor cardiac output is arterial pulse waves analysis but this measurement cannot be reliable during liver transplantation. With the currently technology available, TEE has been the most direct measurement of cardiac filling, offering the benefit of identifying also a variety of other diagnosis that can alter surgical procedure and change the patient's outcome [61].

Training and competencies

Echocardiography is a multifaceted technical expertise and the restrictive factor is the availability of trained operators and equipment. Dobbs et al. conducted a large international web survey to better understand global practice of iTEE in adult cardiac surgery. The results corroborate that the main barriers to the use of iTEE in 27 countries were the lack of resources (equipment and personnel) [62]. However, TEE is being used more often and by more qualified personnel than in previous studies. These results are a call to order to establish basic TEE training programs among novices anesthesiologists as well as among non-skilled seniors, permitting a new generation of physicians who dominate this technique and know how to take advantage in clinical practice of its potential.

Demonstration of competence in iTEE is usually accomplished by successful conclusion of a training program and passing an examination [36].

It is recommended to follow current existing accreditation pathway if one requests to acquire TEE competence. In cardiac surgery, advanced level of echocardiography is required, full diagnostic skills with Doppler modes domain and 3D imaging. Yet, it is possible to a trainee who spends a year in cardiac anesthesia training programme develop required skills to perform a full TEE examination if the equipment can be made accessible. Basic perioperative TE training is mostly dedicated on intraoperative monitoring, whereas advanced training aims on specific diagnoses [63,64].

The European Society of Echocardiography together with the European Association of Cardiac Anaesthesiologists offers a certification in TEE through a two-component evaluation, a multiple-choice examination and the submission of a logbook of 125 PTE exams performed personally in 1-year period. From these studies 15 cases are selected randomly and posterior graded by external examiners. The maintenance of certification requires at least 50 TEEs per year (25 to basic certification) and continuing medical education.

The demands for advanced or director level are not specified in these consensus, but in the ASA and SCA guidelines for training in perioperative echocardiography require 150 and 300 performed TEEs, in advance and director levels, respectively [1,6,64].

New technology allowed the conception of echocardiographic simulators; several studies have been shown an important role in future training of echocardiography skills without routine access to patient environment, demonstrating superior learner outcomes. These platforms are especially important to TEE-naïve since improves expertise, speed learning and comfort with TEE [65-69].

Conclusions

Transesophageal echocardiography information can be very valuable in intraoperative period providing or restoring hemodynamic stability. It should be used as an auxiliary tool to have more comprehensive understanding of the patient's cardiovascular physiology and manage a most adequate surgical intervention. With low risk depending together of experienced skilled operator and patient's anatomy and comorbidities, it is an important perioperative tool that can changes patient's outcome.

Systematic large sets studies are recommendable for access its role in noncardiac surgery, especially since it has been promising in monitoring patients in liver transplantation. Accordingly, it is desirable the adoption of transesophageal echocardiography basic skills within anesthesia practice worldwide.

The crucial worth of iTEE is how the information obtained is interpreted and used to alter the patient management. The risks and benefits should always be considered. Anesthesia and surgical teams should operate together in order to promptly analyze the evidence and act in accordance with the best interest of the patient.

Once expert and skilled, the anesthesiologist increases his position in perioperative medicine, contributing with vital clinical evidence for anesthetic-surgical procedure.

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