ORIGINAL ARTICLE

The importance of intraoperative transesophageal echocardiography in the surgical decision in cardiac surgery

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KEYWORDS
Cardiac surgery; Transesophageal echocardiography; Extracorporeal circulation

Abstract
Objective: To determine the importance of intraoperative transesophageal echocardiography (IOTEE) in the surgical decision in patients undergoing cardiac surgery.

Patients and method: Prospective observational study of patients undergoing cardiac surgery from January 2009 to May 2012, which was monitored with IOTEE by the anaesthesiologist in charge. The data collected were: (1) type of surgery; (2) preoperative echocardiographic diagnosis (baseline ECHO); (3) echocardiographic diagnosis before entering cardiopulmonary bypass (CPB) (pre-CPB IOTEE); (4) any differences between the baseline ECHO and the pre-CPB IOTEE (new pre-CPB finding) and whether these differences modified the planned surgery, and (5) echocardiographic diagnosis after disconnection of CPB (unexpected post-CPB finding) and whether these post-CPB echocardiographic findings led to reinstating it. The software program SPSS® was used for data analysis.

Results: The total number of patients studied was 1273. Monitoring with IOTEE showed ”new pre-CPB” findings in 98 patients (7.7%), and 43.8% of these led to a change in the scheduled surgery. Of these findings, the most frequent were abnormalities of the mitral valve that had not been diagnosed, and which led to a replacement or repair that had not been scheduled. The incidence of ”unexpected post-CPB findings” was 6.2% (79 patients), and 46.8% of those required reinstating the CPB and modifying the surgery performed. The failed valve repairs and dysfunctional valve prostheses were the main causes that led to re-entry into CPB. In


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Importance of intraoperative transesophageal echocardiography

Introduction

Echocardiography is an invaluable perioperative monitoring and diagnosis tool. Intra-operative transesophageal echocardiography (TEE) has increased exponentially in recent years, and it is now used in most cardiovascular surgery procedures and also in certain other non-cardiac interventions.1,2

In 1996, the American Society of Echocardiography and the Society of Cardiovascular Anesthesiologists published the first TEE training guidelines for anaesthesiologists.3 Intra-operative TEE in cardiovascular surgery has five basic clinical indications: (1) monitoring cardiac function and volemia; (2) obtaining new information not available prior to the intra-operative study that can either aid or change the surgical management; (3) postoperative evaluation of valvular repair or reconstruction, allowing surgeons to make on-the-spot intraoperative adjustments, if necessary; (4) guiding the placement of devices or catheters in minimally invasive/keyhole surgery; and (5) detecting complications not shown by other monitoring methods, including left ventricular outflow tract obstruction, intracardiac air, pleural or pericardial effusion, etc.

Studies in cardiovascular surgery have so far shown that TEE performed before or after cardiopulmonary bypass (CPB) can give valuable information on anatomy, valvular
function, disease of great vessels and/or surgical repair, and this can improve the postoperative prognosis of these patients. In our setting, anaesthesiologists and surgeons who use this technique claim that TEE allows them to identify previously undiagnosed diseases during surgery, and to detect residual defects after surgical repair. This enables them in some cases to avoid unnecessary procedures, and in others to correct defects on-the-spot.

The aim of this study was to assess the impact of intraoperative TEE on surgical decision-making in patients undergoing cardiovascular surgery in our hospital.

Materials and methods

A prospective, observation study conducted from January 2009 to May 2012 in patients undergoing on-pump cardiovascular surgery using intraoperative TEE.

The study was approved by the hospital’s Independent Ethics Committee (number 7868). The data were recorded on a pre-designed form during surgery by the anaesthesiologist performing the TEE. The decision to perform TEE was taken by the attending anaesthesiologist, who was also responsible for interpreting the images. Seven anaesthesiologists took part in the study, all with extensive experience in intraoperative TEE in cardiovascular surgery. When the echocardiographic images were hard to interpret and/or suggested the need for significant changes in surgery, they were transmitted via an optical fibre cable from the operating theatre to the echocardiography laboratory where they were reviewed by a specialist echocardiographer.

Exclusion criteria were: echocardiography probe placement contraindicated, no preoperative echocardiogram, no need for probe placement in the opinion of the attending anaesthesiologists, and off-pump cardiovascular surgery. The following information was noted:

1. Planned surgery.
2. Preoperative transthoracic or transesophageal echocardiogram (“baseline echo”).
3. Pre-cardiopulmonary bypass (CPB) echocardiogram (pre-CPB TEE), and whether the results of this study were the same as those of the baseline echo: if not (new pre-CPB finding), whether changes were made to the planned surgical procedure on the basis of these findings.
4. Post-CPB echocardiogram (post-CPB TEE), and whether the results of this study were the same as those of the baseline echo: if not (unforeseen post-CPB finding), whether changes were made to the planned surgical procedure on the basis of these findings.

The data from points 3 and 4 above were used by the anaesthesiologist to complete the following database questionnaire after the procedure:

1. Did the TEE provide new information prior to CPB? Any functional or anatomical information differing from that obtained from the preoperative TEE (baseline echo) was defined as “new information”. We called this new pre-CPB finding “new pre-CPB finding”.
2. Did this “new pre-CPB finding” change the diagnosis or the planned surgery?
3. After CPB disconnection, did the TEE show unforeseen findings related to the planned surgery performed? We called this unforeseen post-CPB finding an “unforeseen post-CPB finding”.
4. Did the “post-CPB finding” change the patient’s post-CPB surgical management?

Two ultrasound systems were used to perform the echocardiography: SONOS 5500 (Philips Ultrasound, Bothell, WA, USA) and SONOS 5500 (Philips Ultrasound, Bothell, WA, USA). The TEE probe was always inserted after anaesthesia induction. Following the recommendations of the American Society of Cardiology, the American Heart Association (AHA), and the European Society of Echocardiography, standard echocardiography was performed prior to CPB and again after disconnection. These are the guidelines followed in our routine clinical practice.

Statistical analysis

Variables are expressed in absolute and relative frequencies; SPSS® v.19 was used to obtain the descriptive analysis of these variables.

Pearson’s chi-squared test was used to assess associations between categorical variables. A p value of <0.05 was considered statistically significant.

Results

A total of 2114 patients underwent cardiovascular surgery between January 2009 and May 2012. Of these, 1273 (60.21%) were monitored by TEE; 62% were men, and 38% women. The mean age was 66±12 years (range 16–89 years).

Fig. 1 shows the total number of cardiovascular surgeries performed and the total number of patients monitored intraoperatively by TEE, distributed by year.

Fig. 2 shows the type of surgery planned in patients monitored by TEE.

“New pre-cardiopulmonary bypass findings”

TEE monitoring presented “new pre-CPB findings” in 98 (7.7%) of the 1273 study patients. In the remaining 1175 patients, the findings of the pre-operative echocardiograms (baseline echo) coincided with those of the pre-CPB study (pre-CPB TEE).

“New pre-CPB findings” related to the planned surgery are shown in Table 1, and were as follows:

1. A total of 381 patients were scheduled for isolated aortic valve surgery (AV), or AV combined with ascending aorta or with coronary bypass; of these, 31 (8.1%) presented “new pre-CPB findings”, the most common being mitral valve disease (12 patients; 38.7%) (Table 1).
2. A total of 157 patients were scheduled for mitral valve surgery (replacement and/or repair), and of these 13 (8.2%) presented “new pre-CPB findings”, the most common being mitral valve disease other than that originally diagnosed in the pre-operative echocardiogram, aortic
or tricuspid valve disease, systolic anterior motion, and patent foramen ovale (PFO) (Table 1). One particularly interesting case was that of a patient scheduled for repair or replacement of the mitral valve due to severe mitral valve insufficiency in whom the "pre-CPB TEE" showed mild insufficiency, despite perfusion of high doses of dobutamine to magnify mitral regurgitation. The case was referred to the echocardiography laboratory, and since the valve showed no signs of structural damage, the planned surgery did not go ahead.

3. A total of 460 patients were scheduled for isolated coronary artery bypass or combined with valve surgery, of which 33 (7.1%) presented "new pre-CPB findings" (Table 1). The most common findings in this group are shown in Table 1. In a separate analysis of patients undergoing isolated coronary artery bypass (n = 311) or combined with valve surgery (n = 149), the percentage of "new pre-CPB findings" was 4.8% and 12%, respectively.

4. A total of 148 patients underwent surgery on 2 or more valves, and of these TEE presented "new pre-CPB findings" in 14 (9.5%). Table 1 shows the most common findings in this group.

5. Finally, "new pre-CPB findings" were detected in 7 (5.5%) out of 127 patients undergoing miscellaneous surgical procedures ("Other" group, Table 1).

We compared surgical procedures with "new pre-CPB findings", observing that the mitral finding (7.4%) is more

Table 1  "New pre-cardiopulmonary bypass findings" related to the planned surgery.

<table>
<thead>
<tr>
<th>Surgery</th>
<th>&quot;New pre-CPB finding&quot;</th>
<th>No./total</th>
<th>Percentages</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>PFO, n/%</td>
<td>Mitral, n/%</td>
<td>AAA, n/%</td>
</tr>
<tr>
<td>AV</td>
<td>4/1</td>
<td>12/3.1</td>
<td>9/2.4</td>
</tr>
<tr>
<td>MRR</td>
<td>1/0.6</td>
<td>3/1.9</td>
<td>0/0</td>
</tr>
<tr>
<td>ACB</td>
<td>2/0.4</td>
<td>14/3</td>
<td>1/0.2</td>
</tr>
<tr>
<td>Double valve</td>
<td>3/2</td>
<td>11/7.4</td>
<td>0/0</td>
</tr>
<tr>
<td>Others°</td>
<td>2/1.6</td>
<td>0/0</td>
<td>0/0</td>
</tr>
<tr>
<td>Total</td>
<td>12</td>
<td>40</td>
<td>10</td>
</tr>
</tbody>
</table>

AAA, ascending aortic aneurysm; double valve, replacement of 2 or more valves; PFO, patent foramen ovale; mitral, mitral valve stenosis or insufficiency; ACB, isolated aortocoronary bypass or combined with valve surgery; MRR, replacement or repair of the mitral valve; AV, replacement of the aortic valve (AVR); AVR = ascending aorta; AVR + coronary bypass.

Values expressed as absolute numbers (n) and percentages (%) of the total number of patients undergoing each surgery.

Chi-squared = 46.95; p = 0.0001.

° Miscellaneous: tricuspid insufficiency, intracardiac thrombi, left ventricular outflow tract obstruction due to systolic anterior motion, aortic atheromas, pericardial effusion and pleural effusion.

° ° Others: cardiac tumours, ventricular septal defect, atrial septal defect, septal myectomy, heart transplant, tetralogy of Fallot.
commonly associated with patients undergoing double valvular procedures than with other surgeries.

Changes in surgical strategy on the basis of ‘‘new pre-CPB findings’’

The surgical strategy was changed in 43 (43.8%) of the 98 patients (7.7% of 1273) presenting ‘‘new pre-CPB findings’’. The new diagnostic findings that most commonly prompted a change in surgical strategy were PFO (72%), aortic valve and ascending aorta disease (66.7%), and mitral valve disease (48.4%).

‘‘Unforeseen post-cardiopulmonary bypass findings’’

In 79 (6.2%) of the 1273 patients, post-CPB TEE showed unforeseen findings (Table 2). These ‘‘unforeseen post-CPB findings’’ are distributed according to surgical procedure as follows:

1. ‘‘Unforeseen post-CPB findings’’ were found in 4.9% (19/381) of patients undergoing isolated AV surgery or combined with ascending aorta or coronary bypass (Table 2).
2. ‘‘New post-CPB findings’’, particularly unsuccessful mitral valve repair (57.1%), were found in 12.7% (20/157) of patients undergoing mitral valve surgery.
3. ‘‘Unforeseen post-CPB findings’’ were found in 4.3% (20/460) of patients undergoing isolated coronary bypass or combined with valvular surgery. ‘‘Unforeseen post-CPB findings’’ were found in 2.2% of the group of patients undergoing isolated coronary bypass, and in those undergoing coronary bypass combined with valvular surgery the percentage was 8.7%.
4. ‘‘Unforeseen post-CPB findings’’ were found in 10.1% (15/148) of patients undergoing surgery of 2 or more valves (Table 2).
5. ‘‘Unforeseen post-CPB findings’’ were found in 3.9% (5/127) of patients undergoing miscellaneous surgical procedures (‘‘Other’’ group in Table 2).

‘‘Unforeseen post-CPB findings’’ were compared with the different surgical procedures, showing that unsuccessful valve repair (7.6%) is more commonly associated with patients undergoing mitral valve replacement and/or repair vs. double valve surgery (1.3%).

Changes in surgical strategy on the basis of ‘‘unforeseen post-cardiopulmonary bypass findings’’

‘‘Unforeseen post-CPB findings’’ occurred in 79 (6.2%) patients, and of these 37 (46.8%) CPB had to be resumed for further surgery. The most common reasons for CPB reconnection were unsuccessful valve repair (15 patients) and prosthetic valve malfunction (15 patients). Ventricular dysfunction requiring coronary bypass (3 patients), residual lesions following atrial or ventricular septum surgery (2 patients), dissection of the ascending aorta (1 patient), and narrowing of the inferior vena cava – right atrium junction (1 patient) were other post-CPB TEE findings that prompted reconnection to the bypass pump.

In the 42 remaining patients with ‘‘unforeseen post-CPB findings’’, the surgical strategy was not changed since the TEE finding was not considered important enough to

<table>
<thead>
<tr>
<th>Table 2</th>
<th>‘‘Unforeseen post-cardiopulmonary bypass findings’’</th>
<th>No./total</th>
<th>Percentages</th>
</tr>
</thead>
<tbody>
<tr>
<td>Surgery</td>
<td>‘‘Unforeseen post-CPB finding’’</td>
<td>Unsuccessful valve repair, n/%</td>
<td>Malfunctioning prosthetic valve or ring, n/%</td>
</tr>
<tr>
<td>AV</td>
<td>3/0.7</td>
<td>6/1.6</td>
<td>0/0</td>
</tr>
<tr>
<td>MRR</td>
<td>12/7.6</td>
<td>3/1.9</td>
<td>0/0</td>
</tr>
<tr>
<td>IAB</td>
<td>3/0.7</td>
<td>3/0.7</td>
<td>0/0</td>
</tr>
<tr>
<td>Double valve</td>
<td>2/1.3</td>
<td>7/4.7</td>
<td>1/0.7</td>
</tr>
<tr>
<td>Othersd</td>
<td>0/0</td>
<td>0/0</td>
<td>1/0.8</td>
</tr>
<tr>
<td>Total</td>
<td>20</td>
<td>19</td>
<td>2</td>
</tr>
</tbody>
</table>

Double valve, replacement of 2 or more valves; ACB, isolated aortocoronary bypass or combined with valve surgery; MRR, mitral valve stenosis or insufficiency; AV, replacement of the aortic valve (AVR); AVR, ascending aorta, AVR + coronary bypass.

Values expressed as absolute numbers (n) and percentages (%) of the total number of patients undergoing each surgery. Chi-squared = 72.48; p = 0.0001.

a Malfunctioning prosthetic valves: periprosthetic and intraprosthetic leakage, hemidisc obstruction, peri-ring leakage.
b Patching: patient with sutured closure of septal defect that had to be re-intervened and patched; double valve patient with stenosis at the entrance of the inferior vena cava and the atrium who had to be reconnected to CPB to widen the vena cava-atrium junction with a patch.
c Miscellaneous: unforeseen aortic valve or ascending aorta surgery, left atrium thrombus, mitral valve insufficiency, tricuspid insufficiency, aortic insufficiency, ventricular dysfunction, left ventricular outflow tract obstruction (systolic anterior motion).
d Others: cardiac tumours, ventricular septal defect, atrial septal defect, ventricular septal myectomy, heart transplant, tetralogy of Fallot.
warrant reconnection to the bypass pump and re-evaluation or change of surgical management.

Discussion

In this study, we found ‘‘new pre-CPB findings’’ in 7.7% of study patients (98 patients); 43.8% of these ‘‘new pre-CPB findings’’ prompted surgeons to change their strategy. Overall, ‘‘new pre-CPB findings’’ prompted a change in surgical strategy in 3.4% of the total number of study patients (1273).

The percentage of ‘‘new pre-CPB findings’’ in our study is slightly higher than that found by Eltzschig et al. in a cohort of 12,566 patients. They found that new echocardiographic findings prior to CPB prompted surgeons to change their strategy in 7.0% of cases.

Skinner et al. also found fewer unforeseen pre-CPB echocardiographic findings in 50 (6%) out of a total of 797 patients; surgical strategy was changed in 34 patients (4%). According to different authors, various factors can explain the difference between preoperative echocardiographic findings and the results of pre-CPB studies: (1) TEE images are usually better than those obtained with transthoracic echocardiography, which is the study most commonly performed on preoperative patients; (2) the quality of the preoperative echocardiogram results could be affected by the cardiologist’s expertise in echocardiography; according to Skinner et al., errors in pre-operative echocardiogram interpretations are both common and significant; and (3) the time elapsed between performance of the echocardiography and the surgery; in the case of a long delay, the disease can progress and affect the pre-operative findings.

To evaluate the evolution of valve surgery patients, the AHA recommends repeating the echocardiogram once or twice a year. Based on these recommendations, some authors suggest that patients on a valve surgery waiting list should undergo echocardiography from 6 and 12 months before surgery. All patients scheduled for cardiovascular surgery should undergo preoperative echocardiography; however, some patients still arrive in theatre without any previous ultrasound study, either because of organizational problems or because the procedure was ruled out by the cardiologist or heart surgeon. For example, patients scheduled for isolated coronary artery bypass often do not undergo preoperative baseline echocardiography.

A new echocardiogram finding affecting the severity of the valvular lesion that comes to light in the theatre after anaesthesia induction usually presents clinicians with a significant dilemma. For example, mitral regurgitation can be underestimated on TEE with the patient under anaesthesia. If it has to be assessed intraoperatively, vasopressor or volume loading drugs are needed to increase systolic pressure. To do this, anaesthesiologists must be trained in echocardiography, and specifically dynamic echocardiography, which is often used in such surgical procedures.

It is best for the patient to have undergone echocardiogram diagnosis before arriving in theatre, and intraoperative TEE should not replace a preoperative echocardiogram.

In our study, patients undergoing surgery on 2 or more valves were more prone to ‘‘new pre-CPB findings’’ (9.5%), followed by those scheduled for mitral valve surgery (8.2%), and aortic surgery (8.1%) (Table 1).

The rate of new diagnosis on pre-CPB TEE relative to the preoperative disease varies enormously from one study to another. In Eltzschig et al., the group of patients scheduled for mitral valve surgery combined with coronary bypass had the highest rate of ‘‘new pre-CPB findings’’ (17.3%), while Click et al. in a series of 3245 patients, found the highest rate of ‘‘new pre-CPB findings’’ among those scheduled for isolated coronary bypass surgery. The authors explained these findings by the fact that only 8% of their scheduled coronary bypass patients had undergone preoperative TEE. In our study, ‘‘new pre-CPB findings’’ were most commonly associated with mitral valve surgery. Intraoperative structural and functional mitral valve evaluation differed most from preoperative echocardiogram findings. Click et al. however, found PFO to be the most common ‘‘new pre-CPB finding’’, occurring in 3.1% of cases. Mahdy et al. also found PFO to be the most common ‘‘new pre-CPB finding’’ (14.4%), followed by mitral valve disease (prolapso or flail) (8.1%) undiagnosed in the preoperative echocardiogram. Our results point to a PFO rate of 12.2% (12/98 patients) (Table 1), and it was closed in 72%. A possible explanation for the lower rate of PFO findings in our study compared to other investigations is that in our setting not all patients were routinely given agitated saline with Valsalva manoeuvre to diagnose this condition. The use of colour Doppler only on bicaval and four-chamber planes and failure to use contrast on a regular basis could have biased our results in terms of PFO persistence. The incidence of PFO might have been higher if we had not acted in this way, although Schmidlin et al., in a series of 1891 patients, reported a PFO rate of 5.3% using agitated saline and Valsalva manoeuvre.

With regard to ‘‘Unforeseen post-CPB findings’’, in our study these were detected on TEE in 79 out of a total of 1273 patients (6.2%). These results concur with those of Click et al., who found ‘‘unforeseen post-CPB findings’’ in 6% of cases studied. However, Mahdy et al. reported a higher rate (14.7%) of ‘‘unforeseen post-CPB findings’’. This disparity could be due to the fact that Mahdy et al. recorded findings that we did not consider, such as: (1) intracardiac air; and (2) location of the intra-aortic balloon pump.

In our study, unforeseen post-CPB findings were most commonly found in patients undergoing mitral valve surgery (79 patients, 12.7%) (Table 2). The most common unforeseen findings were problems involving prosthetic valve or unsuccessful valve repair procedures, forcing surgeons to reconnect CPB and review the valve repair or replace or adjust the prosthetic valve.

Post-CPB echocardiography studies enable surgeons to evaluate the surgery on the spot and make any changes or adjustments needed during the procedure. In our study, the surgeon decided to reconnect CPB to adjust or change the surgery in nearly half the 79 patients (37 patients, 46.8%) with unforeseen post-CPB findings. ‘‘Unforeseen post-CPB findings’’ changed the surgical procedure in 2.9% of study patients (1273 patients). This is in line with Eltzschig et al., where unforeseen post-CPB findings prompted surgeons to reconnect CPB and review the surgery in 2.2% of cases.

Guidelines published jointly by the American Society of Echocardiography, the Society of Cardiovascular Anesthesiologists and the AHA confirm the significant intraoperative impact of TEE in valvular surgery, particular valve repair,
and in coronary bypass surgery with poor ventricular function (indications classes I and IIa), and surgeons can no longer consider performing these procedures without the help of intraoperative echocardiography. However, the benefits of routine use of TEE during coronary bypass with good ventricular function are less clear, and have been given an evidence level of IIb and III, according to the latest recommendations. Despite this, some studies recommend routine use of TEE in all cardiovascular surgery patients, unless probe placement is contraindicated.

In our study, TEE monitoring was used in only 60.2% of cardiovascular surgery patients. The attending anaesthesiologist was responsible for deciding whether the information that could be obtained from TEE justified the risk of the mechanical and thermal injuries that can be caused by the probe.

Unlike Click et al. and Schmidlin et al., we did not evaluate the benefits of TEE in monitoring preloading and haemodynamic response to anaesthetic or cardiovascular drugs.

With regard to the expertise of the 7 anaesthesiologists in charge of interpreting the ultrasound images, 3 had been working with TEE since 1999, had received advanced training in echocardiography, and had passed the European TEE exam, while the remaining 4 had extensive experience in intraoperative echocardiography, with more than 150 studies performed during cardiovascular surgery prior to the start of the study. Differences in the level of expertise of the anaesthesiologists taking part in the study could have biased the pre- and post-CPB study findings, since echocardiography results are preeminently operator-dependent. However, despite the heterogeneity of the attending anaesthesiologists, the rate of findings was similar to that reported in other studies.

In our study, we did not record the number of times attending anaesthesiologists approached expert echocardiologists for a second opinion on hard-to-interpret images, and therefore we cannot know whether less-experienced anaesthesiologists requested help more often. This information would have helped us evaluate the skills of the anaesthesiologists taking part in the study.

The limitations of the study can be summarized as follows: (1) TEE was not performed on all cardiovascular surgery patients; this could suggest that only the most at-risk patients were included in the study; (2) the time elapsed between preoperative and intraoperative echocardiography was not recorded, nor do we know how many patients had undergone a preoperative TEE in addition to the study TEE; (3) we did not record the number of times an expert echocardiologist was consulted; and (4) we did not record intracardiac air, the location of the intra-aortic balloon pump, nor the impact of TEE on changes in drug or fluid therapy. The rate of findings could have been greater if we had evaluated the foregoing events.

In conclusion, this study has shown that intraoperative TEE monitoring in a series of 1273 cardiovascular surgery patients allowed surgeons to diagnose "new pre-CPB findings" in 98 patients, and to change the surgical procedure in 43 of these cases. "Unforeseen post-CPB findings" were detected in 79 patients, changing surgery decisions in 37 of these cases. Despite the limitations of this study, we believe that intraoperative TEE monitoring of cardiovascular surgery patients has been extremely useful in our setting.

Conflict of interests

The authors have no conflicts of interest.

Acknowledgements

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