

# Impact of intraoperative transesophageal echocardiography on surgical decisions in the cardiovascular operating room

## İntraoperatif transözofajiyal ekokardiyografinin ameliyat odasında kardiyovasküler cerrahi kararlarına etkisi

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### ABSTRACT

**Objectives:** To assess the usefulness of intraoperative transesophageal echocardiography (IOTEE) in a cardiac surgery department.

**Study design:** Patients were examined with IOTEE before and after cardiopulmonary bypass. All studies were performed with a Toshiba 270 SSA model imaging device. All IOTEE examinations were performed by two cardiovascular surgery residents who are experienced in IOTEE.

**Results:** A total of 466 patients (239 men, 227 women) were examined by IOTEE from 2001 through 2007. Of these 182 (39%) were performed during correction of valvular pathologies, 193 (41%) during coronary operations, 34 (7%) during combined operations (either valvular or coronary bypass), 8 (1.7%) in adult congenital heart operations, 7 (1.5%) in cardiac mass operations, and the rest in other miscellaneous operations. TEE examinations performed before and after the cardiopulmonary bypass influenced surgical decisions by 14.8% and 9.0%, respectively. Decisions regarding the mitral valve were the most frequent followed by decisions regarding the tricuspid valve.

**Conclusion:** IOTEE significantly affected decision making in cardiac surgery operating room. IOTEE examination must be a standard procedure for all patients undergoing cardiac surgery.

### ÖZET

**Amaç:** Kalp cerrahisi bölümünde intraoperatif transözofajiyal ekokardiyografinin (IOTEE) kullanışlılığı değerlendirildi.

**Çalışma planı:** Kardiyopulmoner baypas öncesi ve sonrası tüm hastalara IOTEE incelemesi yapıldı. Tüm çalışmalarda Toshiba 270 SSA modeli görüntüleme cihazı kullanıldı. IOTEE incelemesi bu konuda deneyimli iki kalp-damar cerrahisi tarafından yapıldı.

**Bulgular:** 2001 ile 2007 yılları arasında 466 hastaya (239 erkek, 227 kadın) IOTEE uygulandı. IOTEE hastaların 182'sinde (%39) kapak patolojisi düzeltme girişimlerinde, 193'ünde (%41) koroner işlemlerde, 34'ünde (%7) kapak ya da koroner baypas işleminde, 8'inde (%1.7) erişkinlerdeki doğuştan kalp hastalıkları operasyonlarında, 7'sinde (%1.5) kardiyak kitle operasyonlarında ve kalanında çeşitli farklı işlemlerde uygulandı. Değerlendirilen hastalarda, kardiyopulmoner baypas öncesi ve sonrası yapılan IOTEE incelemesi cerrahi kararı sırasıyla %14.8 ve %9.0 oranında etkiledi. En sık verilen karar mitral kapakla, sonraki ise triküspit kapakla ilgili idi.

**Sonuç:** IOTEE'nin kalp cerrahisi ameliyathanesinde cerrahi karar verme aşamasında çok önemli etkisi vardır. Kalp cerrahisi uygulanacak tüm kalp hastalarında IOTEE işlemin standart bir parçası olmalıdır.

Intraoperative transesophageal echocardiography (IOTEE) is a safe, semi-invasive procedure, which provides a unique ability to image most cardiac structures at a high degree of resolution. The accuracy of transesophageal echocardiography in

diagnosis of structural abnormalities is quite high, producing results that are reliable and reproducible. Since its introduction in the early 1980's it has become an important standard clinical tool with continuously expanding applications.<sup>[1]</sup> The infor-

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mation obtained from TEE influences important therapeutic decisions in valvular surgery, coronary artery surgery, and thoracic aortic surgery.<sup>[2-5]</sup> Advances in intraoperative monitoring techniques aid the cardiovascular surgeon in patient management and, possibly, contribute to improved outcomes. Although the usefulness of TEE in influencing clinical decisions during valvular heart surgery is well documented,<sup>[6-8]</sup> the clinical utility of routine TEE in patients undergoing all types of cardiac surgery remains unresolved.<sup>[9]</sup>

The aim of this study is to explore the impact of routine IOTEE in cardiac surgery department at a single medical center.

## PATIENTS AND METHODS

### Population Selection

From 2001 to May 2007, 1784 cardiac operations were conducted, consisting of valve dysfunction correction, coronary artery grafting, treatment of aortic disease and removal of cardiac masses in our clinic. Of these, 466 operations were performed in conjunction with complete pre- and post-cardiopulmonary bypass transesophageal echocardiographic imaging, and those evaluations form the basis of this report. The study was approved by the Institutional Review Board.

Our phased array probe is only suitable for adults, and as such the cases evaluated in this study include adult operations only. The patients were informed before the operation about the procedure with a written formatted paper and consent was taken only after questioning regarding swallowing difficulty and other esophageal abnormalities the patient may have experienced. Since 3 patients had a history of swallowing difficulty, and 1 patient had an esophageal operation we could not complete TEE on these patients.

### Echocardiography

All studies were performed with a Toshiba 270 SSA model imaging device and transesophageal probe with a 5 MHz phased array multiplane transducer that permits Doppler Color Flow imaging either with pulsed or continuous wave facilities. All the evaluations were performed by two cardiovas-

cular surgery residents. The IOTEE procedure was performed according to the ASE/SCA guidelines. Because Anesthesiologists qualified and/or experienced in the intraoperative TEE were unavailable to provide a report on examination, all the evaluations were performed by two cardiovascular surgery residents who were educated in Skejby Sygheus Hospital, Aarhus University, Aarhus Denmark.

#### Abbreviations:

|       |   |
|-------|---|
| CPB   | Cardiopulmonary bypass                          |
| TEE   | Transesophageal echocardiography                |
| IOTEE | Intraoperative transesophageal echocardiography |

After induction of general anesthesia and endotracheal intubation, the echocardiographic probe was advanced in the esophagus, 30-45 cm from the teeth. Initial images were obtained before sternotomy incision. The findings were recorded and compared with the cardiologists' observations. All evaluations were recorded on high fidelity video tape and reviewed after surgery by both a cardiologist and a cardiovascular surgery resident for final interpretations. Subsequent images were obtained during the operation as warranted and finally after removal of the patient from cardiopulmonary bypass during chest closure. Standard images of all patients included a long-axis view of the left atrium, left ventricle and the mitral and aortic valves; a transgastric short-axis view of the left ventricle at the papillary muscle level; a four chamber view visualizing the two atrioventricular valves and all four chambers; and an interatrial septal view.

Some images were taken as warranted by clinical circumstances. Doppler color imaging was performed using enhanced maps with an optimal Doppler signal obtained by angulation of the transducer tip to interrogate blood flow in multiple planes in all views.

Left ventricular function was evaluated by comparison of transgastric short axis imaging at midpapillary level and midesophageal 2-chamber or 4-chamber images before bypass and at the end of the operation. Decreased segmental wall motion or a global decrease in contractility was defined as decreased ventricular function.

Valve function was assessed by comparison of pre- and final post-bypass images. Cusp mobility and morphology were evaluated by two-dimen-

sional echocardiography before use of Doppler color flow imaging. Valve insufficiency was graded as first, second, third and fourth degree insufficiency, with first degree insufficiency representing mild and second and third degree insufficiencies defining moderate, and finally fourth degree insufficiency describing severe regurgitant flow.

Interventions were applied to the pooled air identified in pulmonary veins, left atrium, the apex of the left ventricle and aorta. Microbubbles were removed from the related structure of the heart with fine manipulation of needles. The introduction of intraaortic balloon pump (IABP) into the aorta was monitored by TEE. This event is referred to as a post-pump event.

## RESULTS

From 2001 to May 2007, 466 patients were examined by IOTEE. Of these, 182 (39%) were performed during correction of valvular pathologies, 193 (41%) in coronary, 34 (7%) in combined (either valvular or coronary bypass), 8 (1.7%) in adult congenital heart, 7 (1.5%) in cardiac mass, and the rest in miscellaneous cardiac operations. An intraaortic balloon pump was inserted in 29 patients (6%) and IOTEE was used to monitor its precise location. The operations during which TEE was performed have been summarized in Fig. 1.

Baseline characteristics of the patients are given in Table 1.

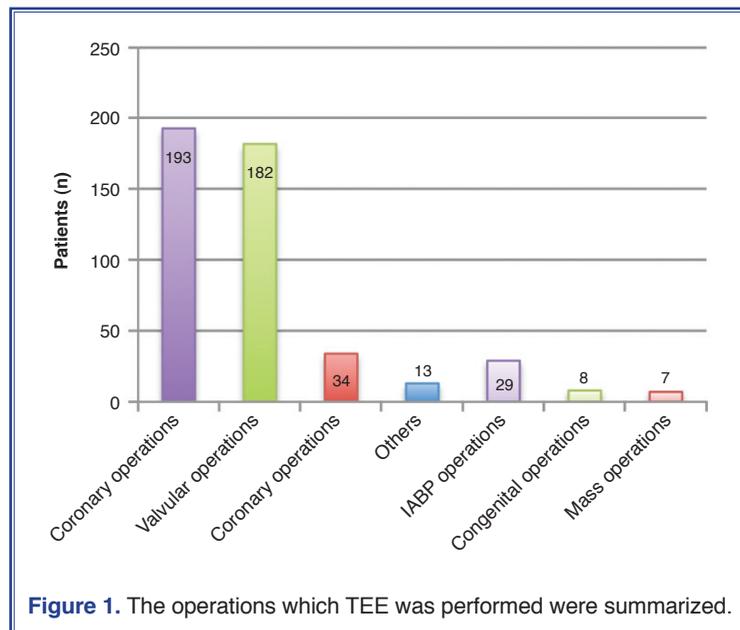
The operative data is summarized in Tables 2, 3, 4. In two cases, post-bypass color Doppler flow imaging was not of sufficient quality to allow for comment on the post-operative results. These patients were evaluated with transthoracic echocardiography post-operatively in the 4th post-operative day and the early out-come of the procedure (mitral valve replacement) was satisfactory. These patients are excluded from this report.

### Pre-pump events

The major findings in the pre-CPB TEE are summarized in Tables 3 and 4. 127 (27.2%) pre-CPB new intraoperative TEE diagnoses affected the surgical decision in 69 (14.8%) out of 466 patients. Decisions regarding the mitral valve were the most common, followed by decisions regarding the tricuspid valve.

In 11 (2.4%) patients who were candidates for mitral valve repair or replacement, left atrial thrombus was detected that had not been recognized by TTE pre-operatively. These were subsequently removed following atriotomy.

In 2 (0.6%) patients over-looked atrial septal defects (ASD) were recognized by IOTEE, which could not be detected by conventional TTE. An iat-



rogenic ASD was detected during venous cannulation of the right atrium. This was corrected following establishment of CPB and cardiac arrest.

A patient (0.3%) developed ascending aortic dissection following aortic cannulation and proximal aortic grafting was performed after initializing CPB from femoral cannulation. Proximal aortic repair was completed successfully. Again, due to aortic cannulation, in 2 patients (0.6%) aortic cannules were repositioned aiming to descending aorta before CPB establishment.

### Post-pump events

The post-CPB IOTEE revealed unexpected findings requiring immediate surgical correction in 42 patients (9.0%): perivalvular leak in 11 patients (9 mitral, 2 aortic), tricuspid insufficiency in 8 patients,

left ventricular dysfunction in 6 patients, incomplete repair in 5 patients (4 mitral, 1 aortic), immobilized leaflet in 4 patients (3 mitral, 1 tricuspid), valve position in 3 patients (1 mitral, 1 aortic, 1 aortic bioprosthesis), high gradient in 2 patients (aortic), coronary obstruction by an aortic bioprosthesis in 2 patients, foreign bodies in 2 patients and prosthetic valve destruction in 1 patient (mitral). A second CPB had to be re-established in 31 (6.6%) patients.

### Aorta

Of the 61 patients undergoing aortic valve replacement (AVR), 7 (11.4%) experienced perivalvular leak, 5 patients (8.1%) were less than moderate, and 2 patients (3.2%) were moderate. 2 (3.2%) patients were found to have perivalvular leakage after aortic valve replacement and of these, the leak

**Table 1. Patients and procedures**

|            | A          | B         | C        | D         | E         | F         | G       | Patients |
|------------|------------|-----------|----------|-----------|-----------|-----------|---------|----------|
| Age (year) |            |           |          |           |           |           |         |          |
| Mean±SD    | 63.14±11.2 | 52.4±17.9 | 58.2±6.4 | 67.4±23.2 | 66.4±22.2 | 25.4±21.2 | 38±10.4 |          |
| Gender     |            |           |          |           |           |           |         |          |
| Male       | 91         | 105       | 13       | 16        | 9         | 3         | 2       | 239      |
| Female     | 102        | 77        | 21       | 13        | 4         | 5         | 5       | 227      |
| Total      | 193        | 182       | 34       | 29        | 13        | 8         | 7       | 466      |

A: Coronary operation; B: Valvular operation; C: Coronary and valvular operation; D: Intraaortic balloon pump locations; E: Others; F: Adult congenital heart disease; G: Cardiac mass.

**Table 2. Operative data of the valvular operations**

|          | MVR | AVR | AVR+MVR | Homograft | Mitral repair | Tricuspid repair | TVR | Aort repair |
|----------|-----|-----|---------|-----------|---------------|------------------|-----|-------------|
| Patients | 109 | 61  | 18      | 3         | 30            | 16               | 2   | 2           |

MVR: Mitral valve replacement; AVR: Aortic valve replacement; TVR: Tricuspid valve replacement.

**Table 3. New intraoperative TEE diagnosis in the pre-CPB period**

|                                  | Mitral valve<br>n (%) | Tricuspid valve<br>n (%) | Aort valve<br>n (%) | Other<br>n (%) | Total |
|----------------------------------|-----------------------|--------------------------|---------------------|----------------|-------|
| Valve not significantly abnormal | 47 (37%)              | 8 (6%)                   | 4 (3%)              |                |       |
| Valve significantly abnormal     | 30 (23%)              | 12 (9%)                  | 8 (6%)              |                |       |
| All of new findings              | 77 (60.6%)            | 20 (15.7%)               | 12 (9.4%)           | 11 (8.7%)      | 120   |
| Affected the surgical decision   | 35 (50.7%)            | 12 (17.4%)               | 4 (5.7%)            | 18 (26.1%)     | 69    |

Valve not significantly abnormal: Significantly abnormal valve according to preoperative data; mid or mild abnormality according to IOTEE.

Valve significantly abnormal: Mild or moderate abnormality according to preoperative data; significant in IOTEE.

All of new findings: Affected the surgical decision: new findings that affects the surgical decision.

**Table 4.** Operative data of the valvular operations

|  | Patients (n) |
|--|--------------|
| Left atrial thrombus                       | 11           |
| Atrial septal defect                       | 3            |
| Intracardiac mass                          | 2            |
| Aorta-right atrial fistula (endocarditis)* | 1            |
| Aortic dissection                          | 1            |

\* Fig. 3.

in a single patient was repaired with extraaortic direct suturing without aortotomy.

In 2 patients (0.6%) prosthetic aortic valves were removed due to high gradient and greater mechanical valves were re-implanted to the aorta following aortic root enlargement procedures.

Impaired left ventricular function attributed to compromised ostial left main flow in patients undergoing AVR with bioprosthetic valves occurred in 2 patients. LAD-saphenous vein bypass anastomosis was made and LV function returned to normal in these individuals.

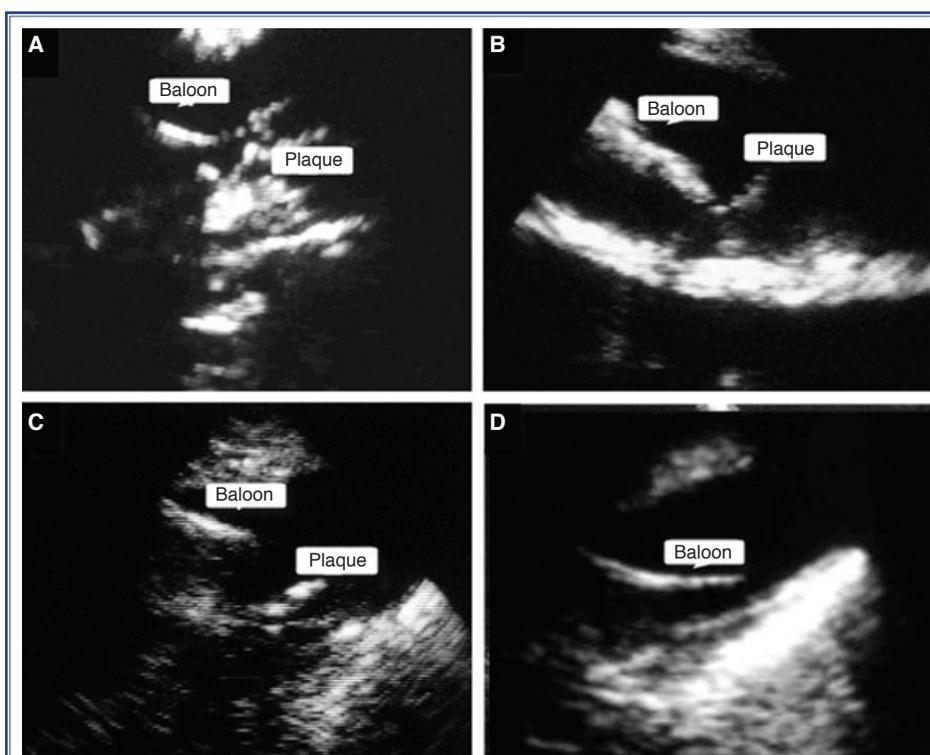
## Mitral

Of the 109 patients undergoing mitral valve replacement (MVR), 24 patients (22%) experienced immediate post-pump perivalvular leak (10.5%), 15 patients (13.7%) were less than moderate, and 9 patients (8.2%) were moderate. Nine patients with a moderate leak underwent immediate repair of the leak. A single mechanical mitral valve (0.9%) was renewed because of prosthetic valve destruction iatrogenically. There were no perivalvular leaks in the tricuspid prostheses.

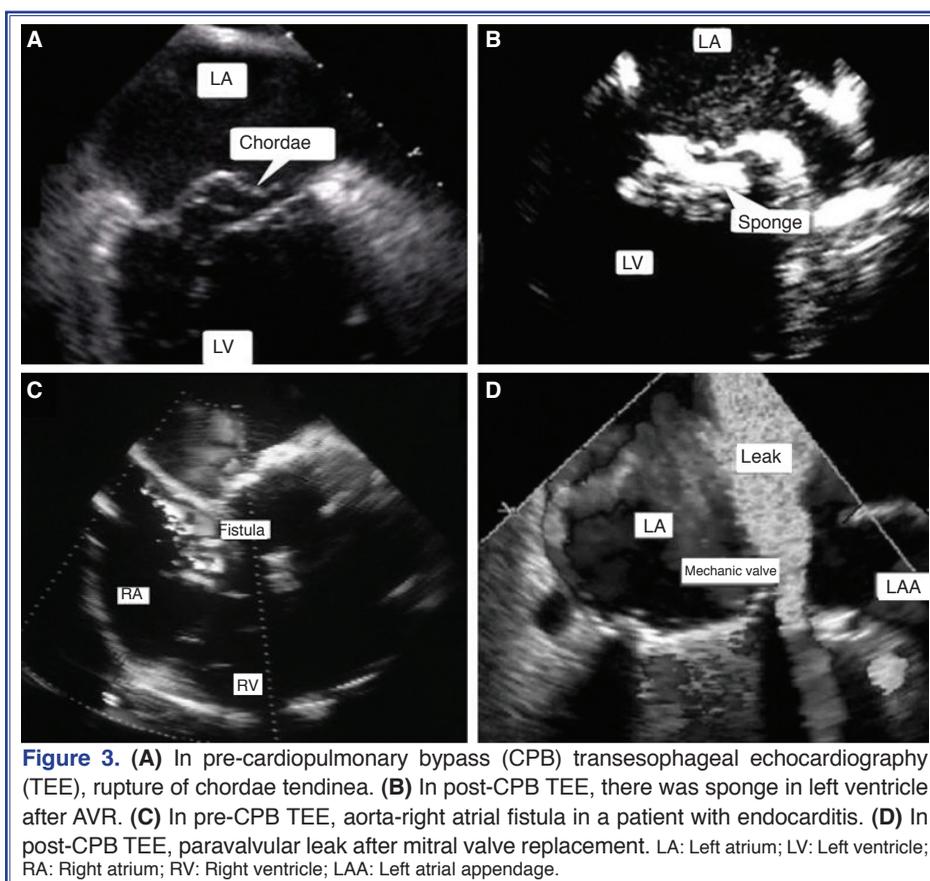
Five (1%) valve replacements were performed following valve repair (4 mitral, 1 aortic) that were detected as incomplete repair after TEE. By the end of CPB, insufficiency was seen to be lasting. More was done particularly in the mitral valve diseases.

## Valve reposition

Of 172 patients with mechanical valves in atrio-ventricular valve position, repositioned leaflet was noted in 3 (1.7%). An aortic bioprosthesis was repositioned which occluded the right coronary artery ostium. 1 mechanical aortic valve was ro-



**Figure 2.** (A, B, C) We determined a marked irregular mass and disruption of the intimal surface of the thoracic aorta in three patients. (D) The balloon catheter was pulled back 3-4 cm from subclavian artery origin to a “healthy” area.



tated because of hemodynamic disturbances due to close contact with hypertrophic muscle mass of left ventricular out-flow tract. 1 mitral valve was rotated due to occlusion of penetrating chordae to the mechanical valve and near-stuck state was impeded either by removing the chordae or rotating the mechanical valves.

### Tricuspid valve

Seven (5.6%) patients needed tricuspid valve repair following mitral valve repair or replacement. Although functional regurgitation was detected secondary to mitral valve dysfunction following mitral hemodynamic restoration, TEE revealed continuing undesirable insufficiency. In a single patient (0.3%) Devegaplasty was tightened until residual insufficiency was reduced.

### CPB-Weaning

In 47 patients (10.1%) the post-pump IOTEE contributed to the evaluation of difficult weaning from the bypass machine and thereby to the proper choice of therapeutic measures (volume expan-

sion, inotropic agents, vasodilators, or mechanical assistance, addition bypass).

Since 6 (12.7%) patients developed left ventricular dysfunction, additional bypasses were performed to enhance cardiac out-put. Those new anastomoses worked well and the patients recovered uneventfully from CPB.

An intraaortic balloon pump was inserted in 29 patients (6.2%) and IOTEE was used to monitor its precise location.<sup>[10]</sup> In 17 (58.6%) of these 29 patients, there was need for further intervention after evaluation with TEE following replacement or repositioning of the IABP. There was no need for any intervention in the other 12 patients. In a single patient (0.3%) IABP rupturing was detected in the aorta and was placed during the operation. In another single patient (0.3%) IABP kinking was detected in the aorta which was placed during the operation and successfully repositioned by TEE monitoring. In 3 patients, severe atherosclerosis (Fig. 2) was detected in de-

scenden aorta which was repositioned by IOTEE monitorizing.<sup>[11]</sup>

### Other

In 2 patients (0.6%) foreign bodies were removed from mediastinum before closure of the chest. They were realized by TEE at the posterior aspect of the heart. One of them was a sponge (Fig. 3b)<sup>[12]</sup> and the other was a needle (Fig. 2).

Intracavitary air was carefully monitored during weaning from the cardiopulmonary bypass machine. Attempts for air removal were continued until there was no pooled air and the microbubbles either disappeared or were reduced to very few. Prolonged air removal (i.e. extension of the bypass time only to assure clearance of air) was required in 26 (5.5%) patients. The procedure usually consisted of leaving the antegrade cardioplegia site open and placing the patient in the Trendelenburg position. Occasionally air was evacuated by left ventricular apical needle application.

In the study period there was 1 patient in which failure to introduce the TEE probe occurred and 1 patient experienced post-operative upper gastrointestinal bleeding caused by esophageal laceration.

## DISCUSSION

This study is the largest study in Turkey examining the influence of intraoperative TEE on surgical decision making in a varied population of cardiac surgery patients. Nonetheless, because intraoperative TEE examinations were not performed in all patients, there was most likely a bias toward examining higher risk patients in whom a favorable impact of TEE was more likely to occur.

It is generally believed that use of TEE in “higher-risk” populations will yield a higher incidence of new findings.<sup>[1,13-22]</sup> The routine use of intraoperative TEE during cardiac surgery remains controversial, especially for lower risk patients (i.e. only for CABG operations).<sup>[23]</sup> Previous investigations have focused on CABG patients with questionable valvular pathology, and have included a low percentage of all patients undergoing CABG in their institution.<sup>[18,24]</sup> Therefore, we examined the utility of TEE in 466 selected patients undergoing differ-

ent types of cardiac procedures. This prospective clinical investigation found that the pre- and post-CPB TEE examinations influenced surgical decision making in 14.8% and 9.0%, respectively, of all evaluated patients.

The pre-CPB TEE examination allows the cardiac surgeon to confirm the preoperative indication for surgery, and therefore to avoid an unnecessary intervention with its associated morbidity. Newly recognized pathologic findings can change the planned procedure, and avoid an additional surgical procedure in the future. This wide range of new findings reported in the literature (10-40%) reflects the great variation in study design and patient populations evaluated (retrospective/prospective, CABG surgery only, valve surgery only, mixed, etc).<sup>[1,13-22]</sup> Similarly, in literature the new intraoperative TEE information altered surgical management in wide range of patients by 5-33%.<sup>[25]</sup> In addition, the most frequent pre-CPB finding was either undetected valve dysfunction or a change in the preoperatively diagnosed valve pathology.<sup>[1]</sup> Our prospective study showed that routine use of intraoperative TEE in patients undergoing cardiac surgery revealed new cardiac pathology in 27.2% of patients is in concordance with previous clinical observations.<sup>[1,13-22]</sup> The new TEE information altered surgical management in 14.8% of patients. 50.72% of the altered surgical management involved the mitral valve, and 17.39% involved the tricuspid valve.

The use of post-CPB TEE imaging to evaluate surgical results is very important. The post-CPB TEE examination can provide a direct and immediate assessment of the surgical procedure, and therefore can expedite the decision to return to CPB when necessary. In recently published prospective studies, incidence of new post-CPB findings that prompted a second CPB run was 2-6%.<sup>[17,24,25]</sup> In our study, immediate surgical correction was required in 9.0%, and a second CPB had to be re-established in 6.6% of the patients. Decisions regarding the mitral valve were the most common (42.9%).

The present study is in accordance with others which report that post-CPB TEE provides new information not only in valvular diseases, but also in

coronary disease and aortic diseases.<sup>[26,27]</sup> In addition to its indispensable role in valve surgery, TEE is also used to continuously monitor cardiac performance.<sup>[26]</sup> There is no doubt that TEE provides invaluable information regarding myocardial contractility and preload, thus clarifying proper treatment of hemodynamic instability.<sup>[1]</sup> In 47 of our patients (10.1%) the post-pump IOTEE contributed to the evaluation of difficult weaning from the CPB. Moreover, TEE is very sensitive in detecting post-CPB myocardial ischemia, new regional wall motion abnormalities associated with possible graft kinking or occlusion, and severely calcified ascending/descending aorta associated with cannulation site/IABP location.<sup>[10]</sup> In our study, a revision of previously placed grafts was required in 6 (1.2%) cases. In 17 IABP inserted patients (3.6%) there was a need for additional interventions after evaluation with TEE.<sup>[10]</sup>

In conclusion, intraoperative TEE has the potential to significantly influence clinical decision making for cardiac surgical patients. It is useful in surgical planning, guiding various hemodynamic interventions, and assessing the immediate results of surgery. Thus, IOTEE should be used routinely in all patients undergoing all types of cardiac/aortic surgery.

**Conflict-of-interest issues regarding the authorship or article: None declared**

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**Key words:** Cardiac surgical procedures; cardiopulmonary bypass; echocardiography, transesophageal; heart valve diseases.

**Anahtar sözcükler:** Kardiyak cerrahi işlemler; kardiyopulmoner baypas; ekokardiyografi, transözofajiyal; kalp kapak hastalıkları.