

Transesophageal echocardiography experience in the pediatric age group in a tertiary cardiac center*

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Background/aim: The aim of this study was to evaluate the transesophageal echocardiography (TEE) findings of pediatric patients in a tertiary center where complex congenital heart surgery and interventional procedures have been performed.

Materials and methods: All TEE studies performed between December 2009 and December 2014 were reviewed retrospectively. Patients were divided into 3 groups: perioperative, during interventional procedures, and due to other reasons. Demographic features, transthoracic echocardiography (TTE) reports, TEE reports, change in decision after TEE evaluation, and related complications were recorded.

Results: A total of 703 patients who had TEE evaluation were included in the study; 51% were female and 49% were male. The median age was 90 months (2 months to 18 years). TEE was performed perioperatively in 430 patients (61%), during cardiac catheterization-angiography and electrophysiology studies in 181 patients (26%), and due to other reasons in 92 patients (13%). Mismatches between TTE and TEE or changes in decision after TEE evaluation were present in 45 patients (10.4%) who had perioperative TEE, in 10 patients (5.5%) who had TEE during interventional procedures, and 22 patients (24%) who had TEE evaluation due to other reasons. No major complications were detected.

Conclusion: Information acquired by TEE increases the clarity of future plans for the patient and helps to decrease the mortality and morbidity caused by unnecessary procedures.

Key words: Transesophageal echocardiography, pediatric patients, cardiac procedures

1. Introduction

Transesophageal echocardiography (TEE) is an important cardiac imaging technique used in pediatric patients with congenital heart disease that aids in imaging the heart and great vessels by a probe introduced into the esophagus and stomach (1,2).

Since it was first used in the 1990s, TEE has been widely in use in children during congenital heart surgery, during interventional procedures, and in intensive care units to evaluate cardiac functions and hemodynamic state. The most important advantage of TEE in comparison to transthoracic echocardiography (TTE) is the opportunity for continuous monitoring and optimal visualization during surgery or invasive procedures. However, the requirement of anesthesia, cost, and potential complications (esophageal trauma, arrhythmia, etc.) are

the primary disadvantages (3,4).

In this study, we evaluate TEE findings and results in pediatric patients in our tertiary cardiac center where congenital heart surgery and interventional cardiac procedures are performed. We aimed to evaluate the indications for TEE, the alterations in diagnosis and treatment strategy after TEE, and the complications of TEE and to discuss and evaluate the findings in detail.

2. Materials and methods

All TEE studies of the pediatric age group between December 2009 and December 2014 were included in the study. A total of 703 patients who had TEE evaluations with an adequate and available file were evaluated retrospectively.

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Patients were grouped into 3 subgroups according to their indications as perioperative (pre- and postoperative) TEE studies, TEE evaluations during invasive cardiac procedures (cardiac catheterization-angiography, electrophysiology studies), and due to other reasons (thrombus, arrhythmia, endocarditis, etc.).

Age, sex, body weight, TTE reports, indication for TEE, TEE reports, changes in final decision after TEE evaluation, and complications related to TEE were recorded in study forms.

Mismatches between TTE and TEE findings, changes in the final surgical strategy or a need for reentry to cardiopulmonary bypass (CPB) after TEE evaluation, change in device size, or abortion of a transcatheter closure procedure after TEE evaluation were recorded, and the presence of one of them was considered a change in decision.

Death, esophagus or stomach perforation, depositioning of the endotracheal tube or extubation, upper gastrointestinal system bleeding, and endocarditis were considered as major complications, whereas temporary airway obstruction, hoarseness, difficulty in swallowing, temporary ventilation difficulties, and compression of the descending aorta were considered as minor complications (5).

TEE was performed with the GE Vivid S5 (General Electric VingMed Systems, Horten, Norway) with biplane pediatric TEE 9T transducer and Phillips IE33 ultrasound machine X7-2t 3D transducer (Phillips Medical Systems, Andover, MA, USA) under general anesthesia in all patients. All TEE evaluations were performed in accordance with the American Society of Echocardiography guidelines (6). Along with a standard transesophageal echocardiographic evaluation, detailed evaluations required for their specific pathologies were also performed for all patients.

Statistical analysis was performed with SPSS 17.0 (SPSS Inc., Chicago, IL, USA). The clinical and laboratory data were presented as median (range).

3. Results

A total of 703 patients were involved in the study; 51% were female and 49% were male. The median age was 90

months (2 months to 18 years), and median body weight was 30 kg (4–65 kg). The demographic data are shown in Table 1.

3.1. Perioperative group

A total of 1650 cases were treated by operation due to congenital heart disease during the study period at our hospital. TEE was performed for 430 patients (26%). The evaluation with TEE was performed for more than one site in some of the patients. In total, 156 patients with ventricular septal defect (VSD), 106 patients with tetralogy of Fallot (TOF), 71 patients with atrial septal defect (ASD), 47 patients with aortic valve pathology, and 34 patients with atrioventricular septal defect (AVSD) were evaluated. Perioperative diagnoses are shown in Table 2.

The surgical strategy was altered in 12 patients (2.7%) after TEE evaluation. Due to residual defects, valve regurgitation, and additional stenosis in 19 patients (4.4%), reentry to CPB was needed. There was incompatibility between TTE and TEE in 14 patients (3.2%), but no change was needed in surgical planning in these patients. Ultimately, alteration in the final decision occurred in 45 out of 430 patients (10.4%) after evaluation with TEE.

The 4 of the 12 cases with decision alteration were pulmonary banding instead of VSD closure after detection of additional muscular VSD in 2 patients and total correction instead of pulmonary banding after the demonstration of small VSD size in 2 other patients after evaluation with TEE. The decision of total correction with transannular patch plasty of the right ventricular outflow tract (RVOT) was changed to VSD closure with aortic valve plasty without any RVOT resection or patch plasty in 3 patients with TOF when it was seen that the cause of RVOT obstruction was aortic valve prolapse towards the RVOT from malalignment of VSD by perioperative TEE evaluation.

Solely the ASD was closed instead of ASD closure combined with relief of pulmonary stenosis after the detection of adequate pulmonary valve opening by TEE and the Glenn procedure was performed instead of total correction in another patient with complete AVSD as chordal straddling and hypoplasia of a ventricle was realized after the TEE evaluation. Mitral valve replacement was performed instead of repair due to severe deformation

Table 1. Demographic features of the patient groups.

Diagnosis	Perioperative	Interventional procedures	Others	Total
Number	430	181	92	703
Sex (female/male)	228/202	78/103	53/39	359/344
Age: months; median (range)	17 (2–180)	120 (60–180)	144 (36–216)	90 (2–216)
Weight: kg; median (range)	10 (4–65)	25 (16–65)	30 (15–60)	30 (4–65)

Table 2. Indications for transesophageal echocardiography.

Diagnosis	n
Perioperative*	430
-Ventricular septal defect	156
-Atrial septal defect	71
-Tetralogy of Fallot	106
-Atrioventricular septal defect	34
-Valvular pathologies	
----Mitral valve	34
----Aortic valve	47
----Tricuspid valve	9
----Pulmonary valve	35
-Left ventricular outflow tract pathology	36
-Glenn procedure	11
-Fontan procedure	6
Interventional procedures	181
- Atrial septal defect closure	154 (5/1)**
- Ventricular septal defect closure	19 (5/4)**
-Electrophysiological study	8
Others	92
-Thrombus, vegetation, mass	31 (19)***
-Patent foramen ovale	20 (3)***
-Arrhythmia	10
-Diagnostic purposes	31

*More than one region was evaluated in some patients.

**Patients that had a difference between the transthoracic and transesophageal echocardiography evaluations/closure were excluded.

***Positive transesophageal echocardiography results are given in parentheses.

of the valve in another patient. Subaortic ridge resection only was performed instead of a Ross–Konno procedure after TEE evaluation of a patient with the preoperative diagnosis of subvalvular and valvular aortic stenosis. An additional subpulmonary defect detected by perioperative TEE evaluation was closed during surgery in a patient with a preoperative diagnosis of lone perimembranous ventricular septal defect and pulmonary hypertension.

At the end of the surgery, 19 out of 430 patients reentered CPB after TEE evaluation. This constituted 4.4% of the patients operated on with the aid of TEE and 1.1% of

all operated patients. A patient with TOF who had residual RVOT obstruction after subvalvular resection to be treated by transannular patch and 3 patients who were operated on for ventricular septal defect for closure of their residual and additional septal shunts reentered CPB. In 3 patients after total correction of complete AVSD valvular repair due to severe regurgitation was performed. In another 3 patients, residual stenosis after operation for valvular and subvalvular aortic stenosis led to reentry to CPB. In 2 patients with double outlet right ventricle, residual left ventricular outflow tract obstruction after the closure of VSD was detected by postoperative TEE evaluation and reentry to CPB was needed. Two patients with corrected transposition of great arteries who were operated on for conduit stenosis needed reentry to CPB after detection of severe tricuspid regurgitation and conduit regurgitation by postoperative TEE. One patient after mitral valve replacement due to opening failure in the recent valve and another patient after Fontan procedure due to excessive antegrade flow and severe AV valve regurgitation needed reentry to CPB. The postoperative TEE evaluations and surgical procedures performed and their results are shown in Table 3.

3.2. Cardiac catheterization and angiography

During the study period cardiac catheterization was performed in 1835 patients. Out of the 1835, transcatheter closure procedure was planned in 154 patients for ASD and in 19 patients for VSD. Preprocedural TEE was performed in all patients. ASD closure was performed via 3D TEE in 8 patients. There was discordance between TTE and TEE in 5 patients with ASD and in 5 patients with VSD. In 1 patient with ASD and 4 patients with VSD, transcatheter closure was discontinued. TEE-guided passage to the left was performed in 8 patients who had ablation on the left side (Table 2). Additionally, 2 patients had TEE-guided interatrial septal stenting or balloon dilatation.

3.3. Other reasons

TEE was performed in 92 patients for different purposes: for differential diagnoses of thrombus, vegetation, or mass in 31 patients (positive result in 19 patients); etiology of migraine, syncope, or transient ischemic attack in 20 patients (positive diagnosis in 3 patients); in 10 patients with atrial flutter or intraatrial reentrant tachycardia for more than 48 h; and in 31 patients with inadequate TTE evaluation for detailed diagnosis. Of the 31 patients, 12 were evaluated with 3D TEE for mitral or aortic valve pathologies.

3.4. Complications

No major complications were detected in any of the patients. Minor complications detected in 7 patients (1%) were transient difficulty in swallowing in 3 patients, a shift in the endotracheal tube and transient airway obstruction

Table 3. Patients that reentered cardiopulmonary bypass after postoperative transesophageal echocardiography.

TTE diagnosis (surgery plan)	Number	Postoperative TEE	Procedure	Control TEE
c-TGA (VSD closure-LV-PA conduit-severe conduit stenosis)	2	Severe tricuspid regurgitation.	Conduit banding.	Minimal tricuspid regurgitation.
		Conduit deformity.	Conduit replacement.	No pathology.
VSD	3	Additional VSD in 1 patient.	Closure of additional defect.	No pathology.
		Patch opening in 2 patients.	New patch.	
Supravalvular AS and subaortic AS	3	Supravalvular and subaortic stenosis.	Relief of stenosis.	No pathology.
Complete AVSD	3	Severe AV valve regurgitation.	Valve repair.	Mild-moderate valve regurgitation.
Fontan procedure	1	Antegrade flow present and severe AV valve regurgitation.	Closure of antegrade flow and AV valve repair.	Mild AV valve regurgitation.
DORV	2	LVOT obstruction in 2 patients.	Dilatation of LVOT	No gradient in LVOT. Complete AV block in 1 patient.
Mitral valve pathology	1	No opening in mechanic mitral valve.	Valve replacement.	No pathology.
Tetralogy of Fallot	4	RVOT obstruction.	Transannular patch.	No gradient at RVOT.

TTE: Transthoracic echocardiography, TEE: transesophageal echocardiography, cTGA: corrected transposition of great arteries, VSD: ventricular septal defect, AS: aortic stenosis, LV-PA: left ventricle-pulmonary artery, AVSD: atrioventricular septal defect, AV: atrioventricular, DORV: double outlet right ventricle, LVOT: left ventricular outflow tract, RVOT: right ventricular outflow tract.

in 2 patients, transient hoarseness in 1 patient, and a ventilation problem in 1 patient.

4. Discussion

TTE has been a safe diagnostic method for congenital heart diseases for years, but in cases where TTE is inadequate, TEE evaluation can be a guide for the pathology (2,3,5). TEE was initially used for postoperative evaluation only, but nowadays TEE evaluation is being used in cases with cardiac thrombus and vegetation, to investigate syncope and transient ischemic attack etiology, and especially during transcatheter procedures to aid ASD and VSD closure simultaneously with fluoroscopy. In this study we evaluated pediatric patients that had TEE evaluation during the perioperative period, during catheterization and interventional procedures, and due to other reasons in 3 categories in our tertiary cardiac center clinic. To our knowledge this is the largest reported pediatric group of patients evaluated with TEE in Turkey.

Perioperative TEE helps to evaluate the initial diagnosis of the patient and to plan additional procedures preoperatively, as well as to evaluate the success of the surgery and to identify any pathology that needs reintervention postoperatively (3,5). In a study by Randolph et al., where the efficiency of perioperative TEE in 1002 patients with congenital heart disease was evaluated, additional pathology was reported in 9.1% of patients. Leading additional findings reported were left to right shunted defects, need for AV valve repair or replacement, or left ventricular outflow tract dilatation. In

2 cases additional VSDs were diagnosed and one of them was surgically closed; pulmonary banding was performed in the other patient (2). Bettex et al. reported additional findings in 13 out of 580 patients (2.2%), mostly left to right shunted defects in perioperative TEE evaluations (7).

Stevenson et al. reported residual defects detected in 17 out of 230 patients, where all were surgically corrected by reentering to CPB. The residual defect incidence was reported as 7.4% by intraoperative TEE evaluation. In this study left ventricular outflow tract obstruction and VSD were reported as the most frequent findings in postoperative TEE for reentry to CPB (8). Ungerleider et al. reported that residual defects were corrected by reentering to CPB in 44 out of 1000 patients (4.4%) (9). Ma et al. reported different findings in 33 out of 350 patients (9.4%) by preoperative TEE evaluation. Reentry to CPB was needed in 13 patients (3.7%) in the postoperative period (10).

In the present study a difference between TTE and TEE findings was detected in 26 (6.1%) out of 430 patients, and surgical planning was altered in 12 out of 26 patients. Residual defects that led to reentry to CPB were shown by postoperative TEE evaluation in 19 patients (4.4%). These were similar to previously reported data.

One of the application fields of TEE in pediatric cardiology is interventional procedures during catheterization and angiography. TEE is an important guide, especially during ASD and VSD closure and transatrial passage during ablation procedures. Although TTE has a high sensitivity in the diagnosis of secundum and primum ASDs, false positive results might happen

because of inadequate visualization of the interatrial septum, as ultrasonic waves may not reach the atrial septum at a correct angle due to its anatomy. False measurement of the defect and the rims results in difficulty or failure during transcatheter closure. TEE enables more detailed morphology in multiple axes as the transducer in the esophagus is much closer to the interatrial septum, no matter the type of device chosen for closure. The atrial morphology, length of interatrial septum, diameter of ASD, the rims, the relation of the ASD to the coronary sinus, caval veins, pulmonary veins, and atrioventricular valves were evaluated in detail by preprocedural TEE. These data identify the suitability of the defect for closure and the device is chosen for closure in light of this information (11). In some studies authors have claimed that TTE has a high success and a low complication rate, similar to TEE-guided procedures, especially in defects smaller than 20 mm (12,13).

Reports have been recently published in literature about 3D echocardiography guidance in many interventional procedures like ASD closure or detailed evaluation of aortic and mitral valvular pathologies. Atrial septal defect size may change during the cardiac cycle and some defects have irregular shapes. 3D echocardiography provides visualization of the entire defect and accurate delineation of atrial septal defect size, which is crucial in selecting an appropriately sized device for transcatheter device closure (14).

ASD closure in our clinic has been done under the guidance of TEE and lately by 3D TEE. 2D and 3D TEE were performed in 159 patients for transcatheter closure. 3D TEE imaging together with 2D measurements enable device selection without balloon sizing in patients with ASD. There was a difference between TTE and TEE evaluations in 5 patients and closure was abandoned in 1 patient.

The perimembranous type and doubly committed subarterial VSD were the major isolated congenital heart defects in children. The transcatheter device closure technique for both types of VSD has emerged as an alternative treatment to surgery. As TEE guidance during transcatheter VSD closure lowered the complications of the procedure and increased the success rates, TEE was accepted as a part of routine procedure. TEE has been performed to estimate the defect size and surrounding structures, especially the distance from tricuspid and aortic valves, tricuspid valve aneurysm, and the presence of aortic valve regurgitation in these procedures (15).

TEE was performed in 19 patients for transcatheter VSD closure. There were differences between the TTE and TEE data in 5 patients, and the procedure was terminated in 4 of them.

Ablation is an important treatment procedure in childhood arrhythmia. There are left-sided accessory pathways or ectopic focus in nearly half of the cases. Patent foramen ovale is an important antegrade transfer pathway to these left-sided regions. Mostly the interatrial septum is intact and transseptal intervention is needed (16). Transseptal puncture has a key role in the increasing array of interventional cardiac procedures in both pediatric and adult patient groups (mitral valvuloplasty, ablation, etc.). Transseptal puncture is a safe procedure in experienced hands, but it still has a complication rate of 1%, and most of these complications, such as tamponade and aortic puncture, are certainly life-threatening. Most of the interventionists perform transseptal punctures either under TEE or intracardiac echocardiography. This enhances the safety of the procedure, but also adds some complications, as well as a general anesthesia requirement in the catheter lab settings (16).

In our study, 8 patients with attainable records had successful transseptal puncture for ablation without any complications under TEE guidance.

TEE is an option, apart from the perioperative period or interventional procedures, in visualization of thrombus or vegetation, in etiologic differentiation of syncope, or where TTE is inadequate for diagnosis. In the case of syncope or transient ischemic attack, the anatomically opened foramen ovale (PFO) might need to be closed (17,18). During TEE evaluation by colored Doppler or agitated serum injection, shunting of blood through the PFO can be definitely shown (14). In a study, out of 85 patients with an interatrial shunt reported by TTE, after the TEE evaluation 37 patients were found to have normal intracardiac anatomy, 36 patients had ASD, and 12 patients had PFO (11). In our study, only 3 out of 21 patients were found to have a PFO that could explain their symptoms.

As surgically opened thorax, obesity, chest deformities, etc. interfere with the quality of TTE views, TEE is needed for the evaluation of thrombus and vegetation in these patients. TEE can also better delineate AV valves, semilunar valves, and the posterior region of the heart (19,20).

Thirty-one patients had TEE evaluation with the suspicion of thrombus or vegetation, and 19 patients had positive results. The cardiac anatomy was enlightened in 31 patients that had inadequate TTE views.

General anesthesia or difficulties in placing the probe into the esophagus might cause some complications. Randolph et al. reported no major complications and a minor complication rate of 1% due to TEE (2). Iwasaki et al. described 3 respiratory and 9 severe hemodynamic changes out of 773 patients, all of whom recovered after taking the TEE probe out, and suggested the use of patient-suitable probe size as well as placing the probe by the help of a laryngoscope to prevent TEE-related complications

(5). In another report, esophagus perforation during perioperative TEE evaluation was reported in a patient in whom a Fontan procedure was planned to be performed (21).

In the present study, transient complications were detected in only 7 patients after TEE evaluation. The complication rate was 1%.

The most important limitations of the study were it being a single-center, retrospective study involving a

heterogeneous group of patients, and the presence of at least 4 pediatric cardiologists performing the TEE evaluations.

In conclusion, TEE is a highly reliable diagnostic method in pediatric patients for the evaluation of determined or suspected pathologies or morphologies, for perioperative evaluation, and for guiding interventional procedures.

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