

Role of intraoperative transesophageal echocardiography in pediatric cardiac surgery



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Background: Intraoperative transesophageal echocardiography (TEE) has a major role in detecting residual lesions during and/or after pediatric cardiac surgery.

Methods: All pediatric patients who underwent cardiac surgery between July 2001 and December 2008 were reviewed. The records of surgical procedure, intraoperative TEE, and pre-discharge transthoracic echocardiograms were reviewed to determine minor and major residual cardiac lesions after surgical repair.

Results: During the study period, a total of 2268 pediatric cardiac patients were operated in our center. Mean age was 21 months (from 1 day to 14 years). Of these patients, 1016 (48%) had preoperative TEE and 1036 (46%) were evaluated by intraoperative echocardiography (TEE or epicardial study). We identified variations between TEE and preoperative transthoracic echocardiography in 14 patients (1.3%). Only one surgical procedure was cancelled after atrial septal defect exclusion. The other 13 patients had minor variation from their surgical plan. Major residual lesions requiring surgical revision were detected in 41 patients (3.9%), with the following primary diagnoses: tetralogy of Fallot in 12 patients (29%), atrioventricular septal defect in seven patients (17%), ventricular septal defect in seven patients (17%), double outlet right ventricle in two patients (5%), Shone complex in two patients (5%), subaortic stenosis in two patients (5%), mitral regurgitation in two patients (5%), pulmonary atresia in two patients (5%), and five patients (12%) with other diagnoses.

Conclusion: Intraoperative TEE has a major impact in pediatric cardiac surgery to detect significant residual lesions. Preoperative TEE has a limited role in case of a high quality preoperative transthoracic echocardiography. We recommend routine use of intraoperative TEE during and/or after intracardiac repair in children.

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Introduction

Transesophageal echocardiography (TEE) has been used intraoperatively since the 1980s [1,2]. In congenital heart surgery intraoperative TEE was useful in confirming the preoperative diagnosis [3,4], evaluation of surgical results as well as in monitoring the cardiac function [5]. The aim of this study is to describe our experience in intraoperative TEE during and/or after repair of congenital heart disease.

Materials and methods

All consecutive pediatric patients (age < 14 years) patients who underwent intraoperative TEE from July 2001 to December 2008 were assessed. A biplane probe was used in the first 166 patients and, later, when it became available, a mini-multiplane probe was used in the rest of the patients. The TEE probe was inserted preoperatively by the anesthetist and was kept in position during the surgery for postoperative study.

TEE was performed by a pediatric cardiologist. Standard views were obtained according to the American Society of Echocardiography Guidelines [2].

Echocardiography reports from patients in the designated study period were reviewed retrospectively on a digital archiving system (Xcelera, Version 2.2; Philips, Eindhoven, The Netherlands). The reviewed reports were classified and characterized as follows. (1) Preoperative transthoracic echocardiography (TTE): defined as the last echocardiography study performed before surgery. (2) Preoperative TEE: consisting of the echocardiography study carried out in operating

Abbreviations

ALCAPA	Abnormal left coronary artery from pulmonary artery
ASD	Atrial septal defect
AVSD	Atrioventricular septal defect
DILV	Double inlet left ventricle
DORV	Double outlet right ventricle
HLHS	Hypoplastic left heart syndrome
LPA	Left pulmonary artery
LV	Left ventricle
LVOT	Left ventricular outflow tract
MR	Mitral regurgitation
MS	Mitral stenosis
MV	Mitral valve
PA	Pulmonary artery
PAPVD	Partial anomalous pulmonary venous drainage
RPA	Right pulmonary artery
RUPV	Right upper pulmonary vein
RVOT	Right ventricular outflow tract
SVC	Superior vena cava
TAPVD	Total anomalous pulmonary venous drainage
TEE	Transesophageal echocardiography
TGA	Transposition of great arteries
TOF	Tetralogy of Fallot
TR	Tricuspid valve regurgitation
VSD	Ventricular septal defect

theater before surgery. This was compared with preoperative TTE to determine variations in diagnosis. If the surgical procedure totally changed or was canceled, this was labeled as major variation in diagnosis. Otherwise the variation was considered minor. (3) Intraoperative echocardiography: consisting of TEE or epicardial study conducted after surgery in the operating theater before revising heparin. Reports were reviewed for residual lesions. A major residual lesion was defined as a lesion which required return on pump for surgical correction. Other abnormal findings which did not require surgical revision were defined as minor

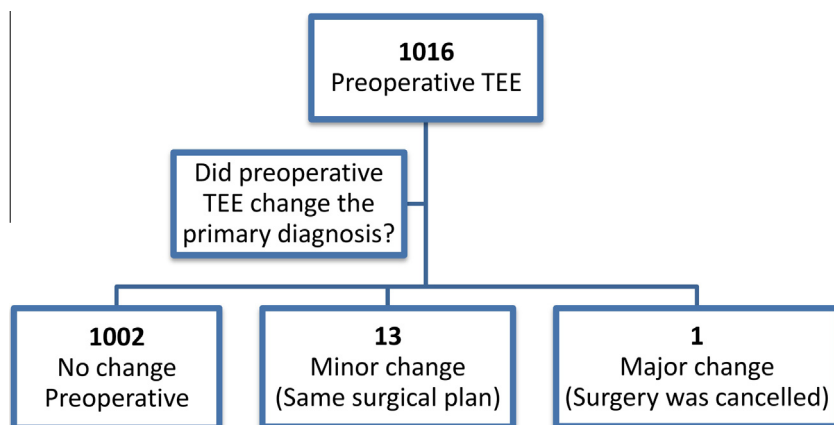


Figure 1. Changes from primary diagnosis in preoperative TEE.

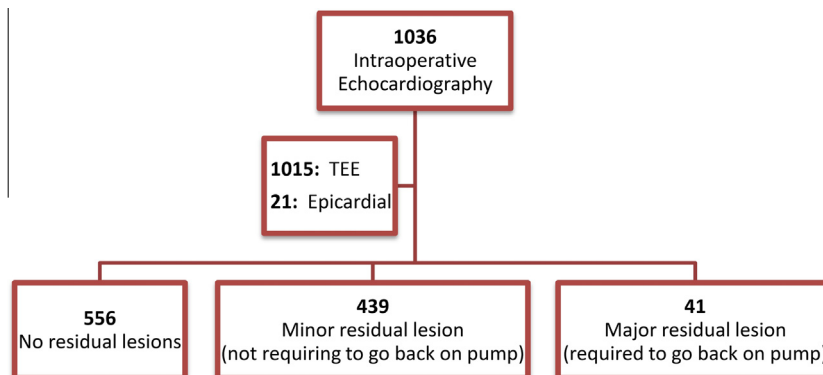


Figure 2. Residual lesions in intraoperative echocardiography.

Table 1. Diagnosis and surgical revision for each diagnosis.

Diagnosis	Total	Surgical revision	% Per diagnosis
TOF	128	12	9
AVSD	165	7	4
VSD	263	6	2
DORV	56	2	4
Pulmonary atresia	44	2	5
Mitral regurgitation	36	2	6
Subaortic stenosis	28	2	7
Shone complex	6	2	33
VSD, multiple	32	1	3
PAPVD	12	1	8
Pulmonary stenosis	10	1	10
ALCAPA	5	1	20
Univentricular heart	5	1	20
Other diagnoses	25	1	4
TGA	108	0	—
ASD	25	0	—
TAPVD	19	0	—
Truncus arteriosus	19	0	—
HLHS	12	0	—
DILV	11	0	—
Tricuspid valve atresia	9	0	—
Congenitally corrected TGA	8	0	—
Aortic stenosis	6	0	—
Cor triatriatum	5	0	—
Total	1037	41	4

ALCAPA = abnormal left coronary artery from pulmonary artery; ASD = atrial septal defect; AVSD = atrioventricular septal defect; DILV = double inlet left ventricle; DORV = double outlet right ventricle; HLHS = hypoplastic left heart syndrome; PAPVD = partial anomalous pulmonary venous drainage; TAPVD = total anomalous pulmonary venous drainage; TGA = transposition of great arteries; TOF = tetralogy of Fallot; VSD = ventricular septal defect.

residual lesions. (4) Predischage TTE was defined as the last echocardiography study performed on the ward before discharge of the patient. Reports were reviewed to determine variations from intraoperative TEE.

Statistical analysis was performed using SPSS version 16 software (SPSS Inc., Chicago, IL, USA).

Results

There were 2268 pediatric cardiac surgery procedures done during the study period. Of these patients, 1016 (48%) had preoperative TEE and 1036 patients (46%) had intraoperative echocardiography (Figs. 1 and 2). Mean age at operation was 21 months (median 7 years, range from 1 day to 14 years), mean weight was 8 kg (median 5.5 kg, range 2–54 kg), and 45% of patients were female. The diagnoses of the operated cases are shown in Table 1. In 21 patients (2%), the insertion of the TEE probe was difficult, so epicardial echocardiography was performed for intraoperative study. Those patients had significantly lower weight and were younger (Table 2).

Forty-one cases (3.9%) had major residual lesions requiring surgical revision after intraoperative echocardiography. All residual lesions were repaired successfully. The age and weight were not risk factors for surgical revision. The most common revision procedures involved right ventricular outflow tract revision of repair in 11 patients (27%), ventricular septal defect (VSD) closure in seven patients (17%), mitral valve second repair in five patients (12%) and mitral valve replacement in three patients (7%; Table 3).

In 14 out of 1016 patients (1.4 %) the preoperative TEE showed variations from the preoperative TTE. Thirteen patients were found to have minor variations and only in one patient the surgical procedure had to be cancelled when TEE ruled out the presence of an atrial septal defect (ASD) prior to surgery (Table 4).

The findings of predischage TTE reports were different from the postoperative TEE findings in 101 out of 1036 patients (10%). In 55 of these 101 patients (55%), a small residual VSD leak was found. Other changes observed are listed in Table 5.

Table 2. Effect of weight and age on type of intraoperative echocardiography.

Intraoperative imaging	n	Age (mo)		Weight (kg)	
		Mean ± SD	p	Mean ± SD	p
Epicardial	21	5.2 ± 4.5	0.024	3.8 ± 2	0.005
TEE	1016	21.5 ± 33.2		8.2 ± 7.1	

SD = standard deviation; TEE = transesophageal echocardiography.

Table 3. Revision procedures.

Revision procedures	Total
RVOT repair	11
VSD closure	7
MV repair	5
MV replacement	3
RPA plasty	2
Tricuspid valve replacement	1
Sternal closure with mesh	1
Main PA plication	1
PFO closure	1
Coarctation repair	1
LV patch release	1
LPA plasty	1
SVC-right atrial junction repair	1
VSD fenestration	1
LVOT repair	1
PA band tightening	1
ASD closure	1
PA band	1
Total	41

ASD = atrial septal defect; LPA = left pulmonary artery; LV = left ventricle; LVOT = left ventricular outflow tract; MV = mitral valve; PA = pulmonary artery; PFO = patent foramen ovale; RPA = right pulmonary artery; RVOT = right ventricular outflow tract; SVC = superior vena cava; VSD = ventricular septal defect.

Table 4. Preoperative transesophageal echocardiography (TEE) variation from preoperative transthoracic echocardiography (TTE) diagnosis.

Preoperative Diagnosis	Variation in preoperative TEE	Total
ASD	ASD, not present	1
AVSD	Left AV valve anatomy	2
	ASD present	1
VSD	MV anatomy	1
	RVOT obstruction	1
Cor triatriatum, ASD	ASD, not present	1
DORV	Additional VSD	1
	Coronary arteries anatomy	1
TGA	Coronary arteries anatomy	1
TOF	Additional VSD	3
Truncus arteriosus	Additional VSD	1
Total		14

ASD = atrial septal defect; AVSD = atrioventricular septal defect; DORV = double outlet right ventricle; MV = mitral valve; RVOT = right ventricular outflow tract; TGA = transposition of great arteries; TOF = tetralogy of Fallot; VSD = ventricular septal defect.

Table 5. Changes in predischarge transthoracic echocardiography (TTE) from postoperative transesophageal echocardiography (TEE).

Changes in predischarge TTE from postoperative TEE	Frequency
VSD leak	55
No VSD leak	15
Severe pulmonary valve regurgitation	9
MR progressed	4
No ASD leak	4
Other VSD	2
TR progressed	2
ASD leak	1
Depressed function	1
LV-aorta tunnel residual	1
LV-right atrium shunt	1
No MR	1
No other VSD	1
No residual coronary shunt	1
No RVOT obstruction	1
PDA	1
Severe aortic valve regurgitation	1
Total	101

ASD = atrial septal defect; LV = left ventricle; MR = mitral regurgitation; PDA = patent ductus arteriosus; RVOT = right ventricular outflow tract; VSD = ventricular septal defect.

Discussion

Intraoperative TEE has a major role in the optimal surgical management for pediatric cardiac surgery. The main benefit of a preoperative TEE study is that it allows the surgeon to review anatomy and findings immediately before surgery [3]. Another series observed high preoperative impact of TEE on the diagnosis up to 9.1% [4]. The lesions that benefited most from intraoperative TEE include complex right ventricular outflow tract repair, atrioventricular septal defect, double outlet right ventricle, left ventricular outflow tract obstruction, mitral or tricuspid valve surgery, and VSDs [3,6,7].

Thirteen patients (1%) required a minor modification of their surgical plan while only one patient required a major change to the planned procedure. This reflects the importance of a high quality preoperative TTE study in the pediatric age group.

However, optimal surgical repair requires accurate preprocedural evaluation followed by critical evaluation of the surgical repair by intraoperative TEE. When a residual lesion is identified it is crucial that the imaging is sufficiently clear to lead constructive discussion between surgeon and cardiologist as to whether to recommence cardiopulmonary bypass (CPB) [7]. The ability to repair the residual lesion should be weighed against the consequences of further period of CPB.

Previous studies have shown a wide variation in the need to resort to a second period of CPB of 4.4–16% [8–11]. A lower rate of about 2.2% is described in an adult series [4] which is thought to be attributed to less anatomical complexity. In our study of mainly pediatric patients, the identification of an important residual surgically correctable lesion led to a second period of CPB in only 3.9% of cases. Missed or an underestimated residual lesions after intraoperative TEE is an important issue that needs to be reevaluated and confirmed with predischarge and follow-up echocardiography studies. Our study demonstrated that as much as 10% of predischarge TTE (101/1036) were found to have some changes compared to intraoperative TEE (Table 5).

Some centers recommend preoperative TEE for all pump and nonpump cases including simple ASDs and VSDs [12]. Smallhorn suggested that complex repair, valve surgery, and outflow tract obstruction most benefited from pre- and postoperative evaluation excluding simple lesions such as ASD, single VSD, and extracardiac defects [5]. We found a limited role of preoperative TEE in the presence of high quality TTE.

The safety of TEE probes has been documented in pediatric patients with small weight. Important complications are rare (2.5%) such as airway obstruction (1%), right main stem advancement of the endotracheal tube (0.2%), tracheal extubation (0.5%), and vascular compression (0.6%) [13]. Esophageal perforation is extremely rare, found in the literature in anecdotal case reports mainly in adults and in one case report in the pediatric age group [14]. Keeping the probe during the procedure until postoperative study is completed is considered a safe practice in our experience while others advocate reinserting the probe at the end of the surgery [5].

Failure of inserting the TEE probe was observed in 21 patients (2%) who had epicardial echocardiography instead of TEE. A similar percentage in pediatric patients has been reported (0.8–1.8%) [10,13]. In another series it was reported that it was not possible to insert the TEE probe in five

out of 145 patients (3.5%); four of them were patients with Down syndrome [15].

The introduction of a new modality such as three-dimensional (3D) TEE is promising for the future as it permits evaluation of the morphology of cardiac defects by comprehensive 3D viewing, such as the defects involved with the mitral valve apparatus [16]. Although this modality is in use for assessment of adequate surgical repair in adults already, a miniaturized 3D TEE probe is not available yet for the pediatric population.

These data were presented in the 21st scientific session of the Saudi Heart Association in February 2010, and was awarded the best abstract prize [17].

Conclusion

Intraoperative TEE has a major impact in pediatric cardiac surgery to detect significant residual lesions. While preoperative TEE has a limited role in the case of a high quality preoperative TTE. We recommend routine use of intraoperative TEE during and/or after intracardiac repair in children.

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