Clinical application value of intraoperative transesophageal echocardiography in pediatric cardiac valvular disease

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Abstract

Background: To explore the value of intraoperative transesophageal echocardiography (TEE) in the surgical treatment of pediatric cardiac valvular disease.

Methods: Transthoracic echocardiography (TTE) was performed in 64 children with cardiac valvular disease, of which 49 patients underwent TEE before and after cardiopulmonary bypass.

Results: The coincidence rate of preoperative TEE with the surgical diagnosis on valvular lesions was 100%, higher than that of TTE (78%). TEE supplemented or corrected 10 cases of TTE valvular lesion diagnosis, improving the accuracy of valvular disease diagnosis. Besides, TEE can effectively evaluate the surgical results.

Conclusions: Preoperative TEE can accurately diagnose valvular disease in children, which helps to develop a surgical plan. Postoperative TEE can find the remaining problems in time and improve the success rate of surgery.

Background

Transesophageal echocardiography (TEE) examination has been widely used in coronary heart disease (CHD) and valvular disease surgery[1–5], showing important value for making treatment decisions. Before the advent of pediatric-specific TEE probes, we used transthoracic echocardiography (TTE) for children with heart disease. Compared with TTE, TEE has better sound-transparent conditions, especially for older children, obese children, and children with significant lung interference.

How to better use TEE to monitor the valve during the perioperative period is of great significance to improve the success rate of surgery and reduce complications. This study performed a TEE examination on patients and compared it with TTE to evaluate the value of TEE in the surgical treatment of children with cardiac valvular disease.

Methods

The present study was approved by the Ethics Committee of Department of ultrasound, Children's Hospital, Zhejiang University School of Medicine, Hangzhou, China. Written informed consent was obtained from all participants.

Patients

From January 2017 to March 2019, 64 children with valvular heart disease were enrolled, including 36 males and 28 females, aged from 1 month to 160 months, with an average of (40.3 ± 41.1) months. There were 36 cases of common atrioventricular canal with valvular disease, 9 cases of Ebstein's anomaly, 8 cases of ventricular septal defect, atrial septal defect and patent ductus arteriosus combined with valvular lesion, 1 case of coarctation of aortic arch with mitral valve disease, 1 case of pulmonary

stenosis with tricuspid valve disease, 2 cases of mitral stenosis with [insufficiency](#), 1 case of mitral valve prolapse with cleft, 2 cases of two lobe malformation of aortic valve, 1 case of aortic-left ventricular canal with aortic insufficiency, and 3 cases of valvular disease caused by infective endocarditis (Figure 1–10).

Transthoracic echocardiography (TTE) was performed in 64 children with cardiac valvular disease, of which 49 patients underwent transesophageal echocardiography (TEE) before and after cardiopulmonary bypass.

Inclusion criteria: patients with congenital or secondary heart valve disease; children with calm coordination, and clear ultrasound images can thus be obtained; patients with at least two times of transthoracic heart Doppler ultrasound; preoperative, intraoperative, and postoperative ultrasound examinations were completed by a doctor with more than 13 years of experience; cardiac function ejection fraction (EF) $\geq 55\%$; hospitalized patients with complete medical records; patients who can actively cooperate with the treatment and follow-up.

Exclusion criteria: patients with valvular regurgitation after heart surgery; patients with unexplained valvular regurgitation; patients who had not been diagnosed by surgical treatment; patients combined with fever, pneumonia (gas would affect the clarity of transthoracic ultrasound images when coughing), chest fluid, and pericardial effusion; cardiac function EF $< 55\%$; patients without postoperative follow-up data.

Methods

TTE was performed on 64 children undergoing surgical treatment with a Philips iE33 color ultrasound system, S8–3 probe, S5–1 probe, GE VividE9 color Doppler ultrasound, M5S probe, and 6S probe. During the examination, the child was placed in the supine position or the left lateral position. The uncooperative person was sedated with 10% chloral hydrate to fully expose the chest. The heart anatomy was routinely scanned to determine whether the heart was deformed, with the valve carefully observed.

During the operation, the Philips iE33 ultrasound system was applied. The S7–3t and S8–3t were inserted through the esophageal probe, and the area associated with heart disease in 49 patients with general anesthesia was examined and compared with preoperative TTE results. The examination information was communicated to the cardiac surgeon in time and compared with the intraoperative findings. After the operation, the heart was re-explored and TEE was used to evaluate the effect of the operation.

Results

Comparison of preoperative TTE and TEE diagnosis results

There was no significant difference in baseline data between patients undergoing TTE and TEE ($P > 0.05$) (Table 1). The coincidence rate of TTE and surgical diagnosis of 64 children was 78% (50/64) (Table 2),

of which 49 patients receiving preoperative and postoperative TEE obtained satisfactory two-dimensional and color Doppler sonograms. Especially for valvular lesions, TEE had more advantages than TTE, clearly showing the shape, echo, opening, and closing of the leaflets, fissures, as well as other malformations in the heart, which were basically consistent with the findings during the operation. Ten patients (Table 3) were diagnosed or corrected by preoperative TEE examination, and the coincidence rate with the surgical diagnosis was 100% (49/49).

Accuracy of the diagnosis of the valvular disease improved by TEE

TEE made a clear etiological diagnosis of valvular lesions diagnosed by preoperative TTE, including 10 cases of supplemental or modified diagnosis, consistent with surgical findings (Table 4).

Postoperative TEE assessment of surgical outcomes

Immediately after the operation, the TEE was evaluated, and 3 cases were found to have significant residual problems. The residual septal flow was greater than 2 mm, and the flow velocity was greater than 3 m/s in two cases; the valve was moderate insufficiency in one case. As the TEE was found timely, it was handled accordingly and the results were satisfactory.

The success rate of 49 cases of TEE probe insertion into the esophagus was 100%. All children were able to tolerate TEE and no adverse complications occurred. For children with cardiopulmonary bypass, ventilatory guidance in the left heart system was performed under the observation of TEE before the end of cardiopulmonary bypass, and air embolism complications did not occur in all children.

Discussion

The most common cause of valvular disease in children is congenital heart disease, followed by infective endocarditis and rheumatic valvular disease. In this group of 64 children, 61 cases were the congenital valvular disease, of which 36 cases (56.25%) were common atrioventricular canal with valvular disease, and 3 cases were caused by infective endocarditis.

The clinical application of TEE in pediatrics has greatly overcome the limitations of TTE and has become an important tool for the diagnosis of cardiac valvular disease in children.

TEE has an advantage in displaying the details of valvular lesions. In this group of patients, the common atrioventricular canal combined with left and right atrioventricular valve lesions, preoperative TEE can clearly show the development of chordae, papillary muscles, and valve leaflets, the degree of regurgitation, as well as small leaflets that are difficult to find by TTE. Postoperative TEE can accurately assess valve regurgitation and residual shunt at the atrioventricular septal repair. For the [Ebstein's anomaly](#), the diagnostic accuracy of TTE is already high. On the basis of TTE, TEE can more clearly show the development of the downward or posterior flap, and accurately measure the distance of the downward movement. TEE is also superior to TTE in the presentation of the mitral, tricuspid papillary muscles and chordae, displaying the abnormally developed papillary muscles and rupture of chordae

tendinca. TEE also accurately displays the number of aortic valve leaflets and the shape of the valve. For a child with aortic-left ventricular anal and aortic valve moderate insufficiency, TEE more clearly distinguishes between the aorta-left ventricle and the incomplete flap. For children with infective endocarditis, TEE can accurately display the size, number, and attachment of neoplasms, as well as the situation of leaflets [6–9]. In a case of the left coronary artery-right atrium with fistula, right atrium and aortic valve have neoplasms, and TEE is consistent with the surgical findings.

TEE can also detect post-operative problems in time and avoid the risk of reopening the chest. It can provide accurate and reliable information to the surgeon before and after surgery, which enhances the surgeon's confidence and effectively improves the success rate of the operation.

There were no complications in this group of patients receiving TEE. The probes designed for infants are softer and can be used for newborns. In addition, professional cardiac ultrasound doctors are required to operate, with correct and gentle manipulation when inserting and removing the probe. For patients with difficulty in insertion, the doctors use a laryngoscope. During the extracorporeal circulation, the TEE probe is frozen and left in the stomach, reducing the number of probes inserted and removed, which can reduce or even avoid the complications of TEE.

Real-time three-dimensional transesophageal echocardiography (RT–3D-TEE) can be acquired in real-time and imaged rapidly, displaying the three-dimensional structure of the heart in multi-directional visions and enabling the accurate analysis of valve anatomy, which is a new method to evaluate heart valve disease[4, 10]. In children, due to weight limitations, it is not currently widely used. Our hospital has performed RT–3D-TEE examinations on some elderly children. It is hoped that in the near future, RT–3D-TEE probes suitable for children will be applied in the examination of pediatric cardiac surgery to provide more intuitive images for the clinic.

Conclusion

Preoperative TEE can accurately diagnose valvular disease in children and postoperative TEE can find the remaining problems in time and improve the success rate of surgery.

Abbreviations

Transthoracic echocardiography (TTE)

coronary heart disease (CHD)

ejection fraction (EF)

Declarations

ETHICS APPROVAL AND CONSENT TO PARTICIPATE

This retrospective study was approved by the Ethics Committee of Children's Hospital, Zhejiang University School of Medicine(Hangzhou, China). All subjects gave written informed consent in accordance with the Declaration of Helsinki.

CONSENT FOR PUBLICATION

All parents, guardians or next of kin provided written informed consent for the minors to participate in this study. Written informed consent was obtained from the patient for publication of this case report and any accompanying images. A copy of the written consent is available for review by the Editor of this journal.

AVAILABILITY OF DATA AND MATERIALS

The analyzed data sets generated during the study are available from the corresponding author on reasonable request.

COMPETING INTERESTS

The authors declare that they had no competing interests.

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AUTHOR CONTRIBUTIONS

JQ performed the examination, collected and analyzed the data, and drafted the manuscript. JY conceived and designed the study, performed the examination. JY helped to collect and analyze the data. XY helped to perform the study and collected the data. LZ helped to perform the study. All authors read and approved the final manuscript.

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Not applicable.

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Tables

Table 1. Comparison of preoperative baseline data between the two groups

	TTE N = 64	TEE N = 49	t/Z/X ²	P
Male [N (%)]	36 (56.25%)	28 (57.14%)	0.009	0.924
Age [M (Q25, Q75) month]	32 (11.67, 61.5)	37 (11.75-66)	0.637	0.524
Body mass index (mean $\pm$ SD, kg/m ²)	15.72 $\pm$ 1.76	15.48 $\pm$ 2.49	0.607	0.545
Heart failure N	0	0	0.00	1.00
Preoperative ejection fraction (mean $\pm$ SD, %)	63 $\pm$ 3.41	62.83 $\pm$ 3.66	0.244	0.808
Heart rate (times/min)	105.41 $\pm$ 18.40	104 $\pm$ 19.29	0.394	0.694

Table 2. Comparison of the compliance rate between TTE and TEE

METHODS	CASES (N)	THE NUMBER OF CASES CONSISTENT WITH THE SURGERY (N)	COINCIDENCE RATE WITH SURGERY
TTE	64	50	78%
TEE	49	49	100%

Table 3. Comparison of TEE diagnosis and TTE diagnosis in 49 children with TEE

Diseases	Cases (N)	Number of cases in which TEE complies with surgery	Number of cases in which TEE complies with surgery
AVSD + Valvular lesion (Figure 1)	22	18	22
Tricuspid valvular deformity (Figure 2)	8	8	8
VSD/ASD/PDA + Valvular lesion (Figure 3 and 4)	8	5	8
Aortic arch constriction + PDA + Mitral stenosis/rupture	1	1	1
PS + Tricuspid stenosis/rupture	1	1	1
Mitral stenosis with regurgitation (Figure 5)	2	2	2
Anterior mitral valve prolapse + posterior lobe rupture (Figure 6)	1	0	1
Aortic valve (bicuspid) malformation (Figure 7)	2	1	2
Moderate regurgitation of aortic-left ventricular tunnel + aortic valve (Figure 8)	1	1	1
Infective endocarditis (Figure 9 and 10)	3	2	3

AVSD, Atrioventricular septal defect; VSD, Ventricular septal defect; ASD, Atrial septal defect; PDA, Patent ductus arteriosus; PS, Pulmonary stenosis.

Table 4. Cases in which TTE diagnosis was supplemented or corrected by preoperative TEE diagnosis

NO.	TTE diagnosis	TEE made supplements or corrections
1	AVSD (excessive type) + left and right atrioventricular valve moderate regurgitation	Multiple ruptures in the left atrioventricular valve (Figure 1A)
2	AVSD (excessive type) + right atrioventricular valve rupture + moderate atrioventricular valve regurgitation	Left atrioventricular valve rupture
3	AVSD (partial type) + tricuspid valve rupture + mitral mid-to-severe regurgitation	Mitral anterior rupture + poor tricuspid development (Figure 1B)
4	AVSD (complete type) + right atrioventricular valve rupture + left atrioventricular valve mild-moderate regurgitation	Left atrioventricular valve rupture
5	VSD + mitral and tricuspid valve regurgitation	Anterior mitral valve prolapse
6	VSD + aortic valve prolapse, moderate insufficiency	Congenital rupture of aortic left coronary valve + non-coronary valve (Figure 3)
7	PDA + anterior mitral valve prolapse with severe regurgitation	Anterior mitral chordae rupture (Figure 4)
8	Left atrial enlargement and moderate mitral regurgitation	Anterior mitral valve prolapse + posterior lobe rupture (Figure 6)
9	Aortic valve (tricuspid) and supra-valvular stenosis	Aortic valve (bicuspid) malformation (Figure 7)
10	Posterior mitral valve neoplasm	Posterior mitral valve neoplasm with perforation (Figure 9)

AVSD, Atrioventricular septal defect; VSD, Ventricular septal defect; PDA, Patent ductus arteriosus.

Figures

Figure 1

Atrioventricular septal defect. A: multiple small fissures of the left atrioventricular valve; B: Right atrioventricular valve cleft.

Figure 2

Ebstein's anomaly. A: Cuspid medialis valvulae tricuspidalis moves downward; B: The tricuspid valve is poorly developed and the tricuspid regurgitation is obvious.

Figure 3

Ventricular septal defect with aortic valve moderate regurgitation. Preoperative TEE shows ruptures of the aortic left coronary valve and noncoronary cusp.

Figure 4

Patent ductus arteriosus with anterior mitral valve prolapse and severe regurgitation. A: Anterior mitral chordae rupture, where anterior leaflet concaves to the left ventricle as a "door arch" when the mitral valve

is open; B: Anterior mitral valve is prolapsed into the left atrium when it is closed, leading to severe regurgitation.

Figure 5

Mitral stenosis with severe regurgitation. A: Mitral valve echo thickening, enhancement, and open limitation are shown; B: The mechanical valve activity is well after mitral valve replacement.

Figure 6

Left atrial enlargement and moderate mitral regurgitation. A: Anterior mitral valve prolapse; B: Mitral posterior valve cleft.

Figure 7

Aortic valve and supra-valvular stenosis. A: Aortic valve stenosis can be seen on the aortic valve; B: Two-lobed malformation of the aortic valve, showing "-" shape when closed.

Figure 8

Aortic-left ventricular canal with aortic valve moderate regurgitation. A: Aorta-left ventricular canal; B: Aortic valve moderate regurgitation.

Figure 9

Infective endocarditis with mitral valve posterior perforation.

Figure 10

Left coronary artery-right atrial fistula complicated with infective endocarditis. A: The neoplasm is visible in the fistula; B: The neoplasm continues to the right atrium, and it is also visible in the aortic valve.