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Summary of the Experiences and Results of Transesophageal Ultrasound-Guided Ventricular Septal Defect and Atrial Septal Defect Closure Operation

Fudong Wang, MM, Wenjun Wang, MM, Qicai Wu, MD, Yuanping Cao, MM, Huang Huang, MD, Ende Tao, MM, Qiao Fang, MM, Liang Tang, MM, Li Wan, MD

Department of Cardiovascular Surgery, First Affiliated Hospital of Nanchang University, Nanchang, Jiangxi Province, China

ABSTRACT

Background: Ventricular septal defect (VSD) and atrial septal defect (ASD) are congenital heart diseases. The techniques of transthoracic closure (TC) and percutaneous closure (PC) for the treatment of VSD and ASD have continuously improved and matured. This study aimed to retrospectively analyze the therapeutic effects of TC and PC on VSD and ASD patients.

Methods: We retrospectively reviewed 928 patients (552 VSD and 376 ASD) who had undergone TC or PC guided by transesophageal ultrasound at the Department of Cardiac Macrovascular Surgery of the First Affiliated Hospital of Nanchang University between August 2010 and August 2020. We collected and evaluated the clinical data of the patients, including age, gender, weight, inlet and outlet diameters of defect, and the operation results of TC and PC. Descriptive statistics were used to analyze means and standard deviations (SD), and the Chi-square test was used to evaluate the difference between groups.

Results: Among the 928 patients who were treated with the closure operation, there were no casualties, with 907 patients (97.7%) showing successful closure. Among the 552 VSD patients who were treated with TC, 540 showed successful close, while 12 cases required extracorporeal circulation after the failure of TC. Among the 376 patients with ASD, 256 patients were treated with TC, of which 251 were successful, and five were failures, including three shedding cases. In addition, among the 120 patients who were treated with PC, 116 were successful, and four were failures, including two shedding cases. Postoperative follow up for patients with successful closure operations demonstrated that the complications of aortic and tricuspid regurgitation, hydropericardium, III° atrioventricular block, shedding of closure umbrella, hemolysis, and thrombosis had not occurred.

Conclusion: Closure operation of VSD and ASD by esophageal ultrasound has the advantages of lower trauma and blood loss, shorter hospital stay, simple operation, fewer postoperative complications, and significant therapeutic efficacy.

INTRODUCTION

Ventricular septal defect (VSD) is a clinically common congenital heart disease that accounts for the morbidity of 20–25% of all congenital heart diseases [Syamasundar 2005]. Atrial septal defect (ASD) is one of the most common congenital heart diseases, representing about 30% of all cases of congenital heart disease [Rao and Harris 2017]. Extracorporeal circulation by heart with ventricular septal defects generally uses traditional surgical treatment for ASD and VSD. The percutaneous catheterization closure operation by X-ray, developed by the Internal Medicine Department, is an effective treatment method for VSD and ASD. However, as X-ray causes certain damage to patients [Marenzi 2004; Wagdi 2009], thoracotomy will be required if the failure of closure occurs, which is difficult for cardiologists to achieve. This has narrowed the clinical application of percutaneous interventional therapy. Transesophageal ultrasound has been favored by clinicians and patients, due to its unique advantages over other transthoracic and percutaneous VSD and ASD closure operations. The minimally invasive VSD and ASD closure operations, since their inception into clinical treatment and through persistent technical improvement, are becoming increasingly mature. In this study, clinical data of VSD and ASD patients undergoing closure operations guided by esophageal ultrasound at the Department of Cardiac Macrovascular Surgery of the First Affiliated Hospital of Nanchang University between August 2010 and August 2020 were retrospectively analyzed.

MATERIALS AND METHODS

General data: Among the 928 patients included in this study, 478 were males (51.5%) and 450 were females (48.5%). The mean age of patients was 8.64 years (SD = 2.42; range: 4 months to 74 years), and the mean body mass was 15.48 kg (SD = 12.91; range: 2.6-64 kg). (Table 1) Among these patients, 552 patients had VSD (59.5%), and 376 had ASD (40.5%). The diagnosis was made by transthoracic echocardiography

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Correspondence: Li Wan, Department of Cardiovascular Surgery, First Affiliated Hospital of Nanchang University, No. 17 Yongwai Zhengjie, Donghu District, Nanchang 330006, Jiangxi Province, China, Telephone +86-18179150406 (e-mail: 3325467350@qq.com).

(TTE), chest X-ray, and electrocardiogram. By analysis of the chest X-ray, 75 patients were diagnosed with pulmonary congestion and pulmonary hypertension.

Preoperative TTE examination revealed that 552 patients suffered from VSD, of which 487 patients including 179 patients with membranous tumor ventricular septal defect (MTVSD), 10 patients, and 55 patients had perimembranous ventricular septal defect (pmVSD), muscular septal defect (MSD), and sub-arterial ventricular septal defect (DCVSD), respectively. (Table 5) Among 376 ASD patients, 323 cases were central-type (oval-shaped) ASD, and 53 cases were inferior vena cava (IVC) ASD. (Table 4)

Inclusion and exclusion criteria: The inclusion criteria for cases to be studied included the following: (1) No contradiction in the diagnosis by preoperative blood biochemical examination, (2) Diagnosis of VSD and ASD with TTE without other inter-cardiac malformations, and (3) The defect did not involve the cardiac valves and was not accompanied by moderate or severe valvular regurgitation. Informed consent was obtained from all individual participants included in this study.

The exclusion criteria for cases to be studied included the following: (1) Infectious disease within two weeks before surgery, (2) Mural thrombus was found in the heart cavity, (3) Hemolytic disease or coagulation dysfunction, (4) Patients with severe pulmonary hypertension or Eisenmenger syndrome, and (5) Patients with decompensated heart failure and left ventricular ejection fraction of < 30%.

Methods of operation: General anesthesia and endotracheal intubation were used. To assess the location, size, marginal conditions, and adjacent valve activity of the defect, a TEE probe was slowly placed in the esophagus.

The TC was performed as follows: (1) A median incision of 1.5-2 cm was taken from the lower sternum running to the upper sternum through a dissection using an electric saw, (2) The pericardium was cut open and suspended, and 1 mg/kg heparin was injected intravenously, (3) Ultrasound of the esophagus was used to locate the defect puncture point on the heart surface, (4) A double needle with gasket and preset purse were placed on the surface of the heart, which was then punctured with a trocar, (5) The guide wire was placed through the defect, (6) The sheath canal was placed along the guide wire and the sheath core was removed, (7) The corresponding size of the blocking device was selected and alternatively released to the left and right umbrella, (8) After the closure device was released completely, the surrounding valve was observed by ultrasound to check whether there was any movement obstacle or defect residual shunt, (9) The steel wire was conveniently withdrawn and removed and it was observed if the closure device clamped firmly, and (10) The exit wire and sheath tube were removed.

The purse was tightened, and a knot was tied in the heart surface after successful transthoracic closure. Bleeding was carefully prevented, and part of the pericardium was closed. After placing the drainage tube, the chest was closed.

The PC was performed as follows: (1) The femoral vein was punctured, and a 6F femoral sheath was placed, (2) A 6F single-curved catheter and a rigid guide wire were inserted through the vagina vasorum, (3) A rotating catheter was forced through the defect region guided by echocardiography and a rigid guide wire was tucked in the left pulmonary vein, (4) The guide wire was retained, and the corresponding closure device was exchanged to pass the sheath canal, (5) Depending on the diameter of the closure device used, a 7–18F delivery sheath was selected, and (6) The guide wire was followed into the left atrium, and the sheath-core was removed, followed by the same steps as the transthoracic approach. Moreover, for patients with PC, the puncture point was pressed for at least 15 min to stop bleeding, and the elastic bandage was pressurized and wrapped for 4–6 h.

All patients were asked to orally take aspirin (3–5 mg/kg) for 3–6 months after surgery, and echocardiography and electrocardiography were performed again after one month, three months, six months, and one year after surgery. Afterward, patients were annually re-examined.

Evaluation of the operation results: The operation results were classified based on the success of the operation, that is, smooth closure, difficult closure, successful closure, and failing closure. Smooth closure indicated that the puncture point was accurate, the guide wire and sheath canal smoothly passed, and the closure device was firmly clipped. Difficult closure indicated that it was difficult for the guide wire and sheath canal to pass through the defect or the closure device was not in line with the diameter of the defect, which made it necessary to adjust the puncture point or replace the closure device to complete the closure. Successful closure represented smooth closure or complete closure after the adjustment of difficult closure. Failing closure indicated that the closure device could not be attached or was forced to be abandoned, due to valve dysfunction and atrioventricular block after implantation.

Patient follow up: A total of 907 patients with successful closure were re-examined at 1 month, 3 months, 6 months, and 12 months, respectively, after surgery by cardiac color ultrasound to check whether there was residual shunt or cardiac valve activity disorder. The ECG was reviewed to determine whether there were any symptoms of atrioventricular conductional block. Telephonic follow up was conducted for patients for over 2 years after the operation, at intervals of 3, 5, and 10 years after the operation, and the growth status, activity ability, related secondary surgery, or any other complications were recorded.

Statistical analysis: The statistical software SPSS version 22.0 was used to analyze the data. The descriptive statistics were used to calculate means, SD and percentage, and the measurement data were expressed as mean (SD, range) or n (%). The Chi-square test was carried out to assess the difference between groups, and a P-value of < 0.05 indicated statistically significant differences between groups.

RESULTS

3.1 Results of the operation

As shown in Table 2, 907 cases (97.7%) were successful closures without any casualties, due to the operation or related

Table 1. General information of patients with congenital heart disease

Group	Case (*N*)	Gender (Case, male/female)	Age (months or years)	Weight (kg)	Defect diameter (mm)
VSD	552	268/284	4 months-29 years	2.6-64	2-11
ASD	376	210/166	8 months-74 years	3.5-64	3-36

Table 2. Results of minimally invasive closure surgery in cases of VSD and ASD

Group	Successful closure	Failing closure (shedding closure cases)	Success rate (%)
VSD	540	12 (-)	97.8
ASD	367	9 (5)	97.6
Total	907	16 (5)	97.7

Table 3. Effects of different approaches on the closure of VSD and ASD patients

Group	Thoracic approach – Success	Thoracic approach – Failure (shed cases)	Percutaneous approach – Success	Percutaneous approach – Failure (shed cases)	Total
VSD	540	12 (-)	-	-	552
ASD	251	5 (3)	116	4 (2)	376
Total	791	17 (3)	116	4 (2)	928

Table 4. Statistics of atrial septum types and closure pathways

Group	Transthoracic closure	Percutaneous closure	Total
Central type (oval hole)	223	100	323
Inferior vena cava	33	20	53
Total	256	120	376

Table 5. Results of cases with VSD closure

Group	Type and diameter of pmVSD									
	Pure pmVSD (*N* = 308)	MTVSD Single outlet and inlet diameter ≤ 10 mm (*N* = 68)	MTVSD Multi-outlet and inlet diameter ≤ 10 mm (*N* = 90)	MTVSD Multi-outlet and inlet diameter > 10 mm (*N* = 21)	MSD (*N* = 10)	DCVSD (*N* = 55)	*P*1	*P*2	*P*3	*P*4
Smooth closure	297	65	83	12	4	47	0.596	<0.001	<0.001	0.101
Difficult closure	10	3	5	4	4	6	1.0	0.087	0.002	0.304
Failing closure	1	-	2	5	2	2	0.507	<0.001	0.015	0.198

*P*1 represents the comparison between single-outlet and inlet diameter (≤ 10 mm) and multi-outlet and inlet diameter (≤ 10 mm) in MTVSD patients. *P*2 represents the comparison between single-outlet and inlet diameter (≤ 10 mm) and multi-outlet and inlet diameter (> 10 mm) in MTVSD patients. *P*3 represents the comparison between MTVSD patients with single-outlet and inlet diameter (≤ 10 mm) and MSD patients. P4 represents the comparison between MTVSD patients with single-outlet and inlet diameter (≤ 10 mm) and DCVSD patients.

actions. All VSD patients (N = 552) were subjected to TC, with a success rate of minimally invasive closure surgery of 97.8%. (Table 3) (Table 2) Besides, among the VSD patients who were subjected to TC, 12 cases showed failing closure, and no one showed shedding closure. Among the 376 ASD patients, 367 cases (97.6%) were successful closure, while nine patients showed failing closure, including five cases of shedding closure (Table 2). Furthermore, 256 ASD patients and 120 ASD patients were treated with TC and PC, respectively (Table 3), among which 251 patients and 116 patients, respectively, showed successful closure. Among the ASD patients subjected to TC, five cases were of failing closure, including three of shedding closure. Among the patients subjected to PC, four were failing closure, including two of shedding closure (Table 3). Among the 256 ASD patients subjected to TC, 223 were central type (oval hole) patients and 33 were inferior vena cava, while among the 120 ASD patients subjected to PC, 100 were central type (oval hole) patients and 20 were inferior vena cava (Table 4).

The mean diameters of the defect of VSD patients and ASD patients were 5.35 (SD = 1.25, range: 2-11 mm) and 17.52 (SD = 4.27, range: 3-36 mm), respectively (Table 1). Among the VSD patients, 297 pure pmVSD patients were smooth closures, and only one case was a difficult closure (Table 5). Among the 179 MTVSD patients, there were no failing closure patients with a single outlet and inlet defect diameters of < 10 mm, while two patients with multi-outlet and an inlet diameter of < 10 mm and five patients with an inlet diameter of > 10 mm needed chest opening and repair after the breakdown of closure. Moreover, 12 MTVSD patients were difficult closures. Among 10 patients with MSD, four patients with difficult closures and two patients with breakdown situations of closure were observed. Moreover, six patients with arduous closure and two patients with thoracotomy mend after breakdown of closure were observed among the 55 DCVSD patients. Furthermore, the numbers of MTVSD patients with single outlet and inlet diameter (≤ 10 mm) and MSD patients with smooth closure ($P < 0.001$), difficult closure ($P = 0.002$), and failing closure ($P = 0.015$) were significantly different. In MTVSD patients, the numbers of patients with single outlet and inlet diameter (≤ 10 mm) and those of patients with multi-outlet and inlet diameter (> 10 mm) in smooth closure ($P < 0.001$) and failing closure ($P < 0.001$) also showed statistically significant differences.

There were 24 ASD patients with difficult closure, among which 14 had been treated with PC. These 14 patients were mainly those with a defect diameter of > 5 mm, while only one patient with a difficult closure had a defect diameter of < 5 mm. (Table 6) (Table 7) Among the ASD patients treated with TC, 10 with a defect diameter of > 10 mm showed difficult closure. Among the ASD patients treated with PC, four patients with a defect diameter of > 20 mm showed failing closure. The ASD patients treated with TC showed failed closure only in case of defect diameters of > 25 mm (N = 5). Among these five patients, two cases were subjected to extracorporeal round flow thoracotomy mending, and three shed the closure

Table 6. Influence of ASD defect diameter on the results of percutaneous closure

Group	Defect diameter of ASD patients						
	≤ 5 mm (*N* = 35)	>5 ~ ≤ 20 mm (*N* = 45)	> 20 ~ ≤ 35 mm (*N* = 26)	> 35 mm (*N* = 14)	*P*1	*P*2	*P*3
Smooth closure	34	41	20	7	0.522	0.193	0.002
Difficult closure	1	4	4	5	0.522	0.657	0.044
Failing closure	-	-	2	2	-	0.131	0.053

*P*1 represents the comparison between the defect diameter of > 5 mm and < 20 mm and the defect diameter of < 5 mm. *P*2 indicates the comparison between the defect diameter of > 5 mm and < 20 mm and the defect diameter of > 20 mm and < 35 mm. *P*3 represents the comparison of the defect diameter of > 5 and < 20 mm and the defect diameter of > 35 mm.

Table 7. Influence of ASD defect diameter on the results of transthoracic closure

Group	Defect diameter of ASD patients							
	≤ 10 mm (*N* = 86)	> 10 ~ ≤ 15 mm (*N* = 55)	> 15 ~ ≤ 20 mm (*N* = 72)	> 20 ~ ≤ 25 mm (*N* = 25)	> 25 mm (*N* = 18)	*P*1	*P*2	*P*3
Smooth closure	86	54	71	22	8	1.0	0.086	<0.001
Difficult closure	-	1	1	3	5	1.0	0.086	<0.001
Failing closure	-	-	-	-	5	-	-	<0.001

*P*1 represents the comparison between the defect diameter of > 15 mm and < 20 mm and the defect diameter of > 10 mm and < 15 mm. *P*2 represents the comparison between the defect diameter of > 15 mm and < 20 mm and the defect diameter of > 20 mm and < 25 mm. *P*3 represents the comparison between the defect diameter of > 15 mm and < 20 mm and the defect diameter of > 25 mm.

device. Moreover, among the patients treated with PC, the number of patients with a defect diameter of > 5 mm to < 20 mm and those with a defect diameter of > 35 mm in smooth closure (P = 0.002) and difficult closure (P = 0.044) was significantly different. Among the patients treated with TC, the number of patients with a defect diameter of > 15 mm and < 20 mm and those with a defect diameter of > 25 mm in smooth closure (P < 0.001), difficult closure (P < 0.001), and failing closure (P < 0.001) also was significantly different.

Results of follow up: During the 10-year follow-up period, 845 patients (91.1%) were followed up, and the majority of patients were found out of contact. There were five cases with the shedding of the closure device, which included three cases by the thoracic ASD approach and two cases by the percutaneous ASD approach. However, shedding of the closure device was not observed after the VSD closure operation.

DISCUSSION

Presently, the treatment strategy for inborn heart sickness generally includes traditional open operations, percutaneous catheter intervention, all types of minimally intrusive operations with a small cut, shooting-assisted thoracoscopic operations, and machine-assisted operations. Although traditional surgery is independent of patient age, body mass, diameter, and location of the defect, it has an advantage, especially for patients of a young age, low-body mass, and pulmonary hypertension, even if the interventional therapy has failed. However, these methods have some drawbacks. For example, central thoracotomy and extracorporeal circulation in traditional surgery will cause great trauma to the body, accompanied by high intraoperative blood loss, slow postoperative recovery, unaesthetic incision healing, and a great influence on postoperative respiratory function in high-risk patients. Long hours of video-assisted thoracoscopic and robot-assisted systems are required to master complex operations. Percutaneous catheterization is required to be performed under the guidance of X-ray angiography, which may cause some damage to patients and medical staff. If the closure fails, it is difficult for cardiologists to apply cardiopulmonary bypass thoracotomy repair, which limits the clinical applications of this method for the treatment of congenital heart disease [Amin 2004; Amin 2006; Argenziano 2002; Bacha 2005; Ewert 1999; Jung 2010; Kikuchi 2010; Malhotra 1999; Martínez 2011; Mitamura 2014; Moran 2013; Sarris 2010; Wayne 2011; Woo 2006].

A previous study reported that minimally invasive techniques guided by transesophageal echocardiography and epicardial echocardiography were feasible and effective for the closure of periventricular muscular VSD, and among the 11 children with muscular VSD, six children were qualified for the device closure [Haponiuk 2013]. Another study also demonstrated that hybrid procedures mediated by epicardial echocardiography imaging were effective for large pmVSD [Chojnicki 2011]. After the right ventricle of infants with multiple-muscular VSD is punctured under the guidance of transesophageal echocardiography, an 8-mm device closure is implanted, leading to complete closure in all infants with VSD within 11 months after surgery [Haponiuk 2011]. Minimally invasive operation closure operation combines the benefits of open-vision mend under extracorporeal distribution and percutaneous catheter intervention, showing the advantages of quickness, agreeable, malleability, adaptability to surgery, and enhancement of the results of related surgery and internal medicine. Simultaneously, it can reduce surgical risk and trauma, avoid injury due to X-ray and catheter intervention, improve surgical efficacy, and reduce various complications [Andreassi 2006; Cardis 2007; Fazel 2009; Milkovic 2009; Pedra 2010; Schmitz 2008]. The operation follows two approaches, transthoracic or percutaneous. The TC approach has the advantages of a short path, wide indications, and feasibility across all patient ages. Furthermore, an ultrasound of the esophagus can be used for the evaluation of the procedure to check for valve activity disorder and III atrioventricular blocks after the implantation of the closure device. Thus, if closure failure occurs and the closure device is shed, we can immediately turn to thoracotomy as a priority for ASD or VSD. The PC approach, which does not involve intraoperative X-ray, is non-polluting, least invasive, and provides surgical support, and it is frequently applied in pediatric ASD.

Based on embryonic development, VSD is generally divided into three types: perimembranous, funnel (intercristal VSD and DCVSD), and muscular VSD. Perimembranous is the most common. In this study, there were 487 cases of pmVSD, including 179 cases of neoplasia in the membranous part. All VSD patients took the thoracic approach, resulting in 540 successful cases of VSD closure and 12 cases of failure closure, which were mainly observed in DCVSD, MSD, and MTVSD with multi-outlet and inlet diameter. In the case of DCVSD, the defect is located in the rear lower area of the opening of the ventricular outflow tract, aorta, and pulmonary artery, which adds to the difficulty of closure. Intuitively, parts of the pulmonary valve ring and the aortic valve ring constitute the upper edge of the defect. If the defect is large, the anterior part of the right coronary valve can be seen through the defect, leading to intraoperative injury of the aortic valve. According to experience, a special high-and low-partial heart-shaped closure device was selected for the closure of DCVSD, with remarkable effect. The closure of DCVSD requires an accurate measurement of the anatomical defects, and the high-and low-eccentric closure umbrella was selected to reduce the influence of the edge of the closure umbrella on the conduction beam. Because of its small left-ventricular surface, there was no possibility of it affecting the opening and closing of the aortic valve.

VSD membranous tumor is distinguished by a large base diameter, narrow wall, numerous incisions, and weak surrounding tissue of the incision, increasing the level of difficulty for closure. Thus, preoperative assessment and the choice of interoperative closure tools must be accurately made. According to experience, the success rate of patients with VSD preoperative auscultation evaluation, loud auscultation area noise, and limited scope is higher. To select the closure device model, diameters of 1-2 mm and 4–6 mm more than the diameters of the VSD defect and ASD defect,

respectively, were adopted. Compared with the transthoracic VSD closure, the percutaneous approach showed defects such as long path, poor hand feel, poor controllability, and difficulty in pre-expansion. The TC approach involves three routes: through the 1/3rd median lower of the sternum, the left para-sternum, and the right atrium. The first route is the most widely used in clinical practice. According to different types of VSD, the corresponding surgical pathways can yield satisfactory clinical results.

The location and size of ASD vary greatly, with the most common diameter ranging from 15 to 30 mm. In this study, the defect diameter of ASD patients ranged from 3 to 36 mm. However, from the perspective of clinical imageology, the defect varied from 10 mm to nearly the entire atrial septum. Previous literature reported that ASD patients with a defect diameter of < 8 mm showed self-closure [Knop 2014; McMahon 2002], although the possibility of self-closure after the age of 5 years old was very small. In this study, ASD was the secondary hole type, which is divided into the central type (oval hole type), inferior vena cava type, superior vena cava type, and mixed type, according to the site of the defect. However, among the 376 patients with ASD, only two types were observed, with the central type (323 cases) being the most common, followed by the inferior vena cava type (53 cases).

The history of ASD treatment can be traced back to the 1960s. It has been reported that the interventional treatment of ASD has significantly progressed in the past few years. Compared with the other surgical methods, this method has the advantages of short hospital stays and fewer complications [Cowley 2001]. Recently, with the development of minimally invasive technology, minimally invasive surgical closure operation has been widely performed in clinical practice [Chen 2012; Hongxin 2007]. Operations by the transthoracic and percutaneous approaches also can be adopted for ASD closure guided by esophageal ultrasound. In this study, 256 and 120 ASD patients were operated on using transthoracic and percutaneous approaches, respectively. Most ASD patients with a small defect diameter, including patients who received PC (defect diameter of ≤ 5 mm) and TC (defect diameter of ≤ 10 mm), showed successful closure, with only one patient treated with PC (defect diameter of ≤ 5 mm) showing difficult closure and no patients showing failing closure. ASD with a small diameter is mainly of the central type, and the guide wire and sheath canal will be blocked by the secondary septum in TC, which will lead to difficult closure or even failing closure. As the direction of the guide wire and sheath canal was opposite to the defect opening, the success of the PC increased.

For ASD patients with a defect diameter ranging from 5 mm to 20 mm, both approaches are available, but the PC was the least invasive. It is particularly important to adjust the release angle of the closure device during ASD percutaneous closure operation. To achieve the best surgical result, the catheter should be inserted into the left upper pulmonary vein through the leading wire such that the release angle of the closure device is at a right angle to the defiance plane. It also is necessary to guard against the rupture of the guide wire caused by disruption into the left cardiac ear. According to general clinical experience, ASD patients with a large defect diameter (20-35 mm) were better treated by esophageal ultrasound-guided transthoracic closure. Resulting in the difficulty in vascular dilation and the inability to maintain the leading cable and sheath canal in patients at a right angle to the defiance plane, the rate of intraoperative umbrella and replacement, the difficulty of closure, and the probability of failure, percutaneous closure is seldom used. ASD patients with very large defect diameter (> 35 mm) had good defect edge conditions, a short operation path, and a good release angle of the selected closure device. However, the difficulty of closure and possibility of failure in these patients were significantly higher than those of ASD patients with a defect diameter of < 35 mm, and the closure device was likely to be shed after surgery.

There were five cases of the shedding of the closure device in patients after ASD surgery and two cases of the shedding of the closure device among patients with a defect diameter of > 35 mm after percutaneous surgery. Moreover, three cases of shedding of the inferior cavity defect on the 3rd day after the thoracic operation were recorded due to poor marginal conditions and poor clamping of the closure device. All five patients received thoracotomy, with the closure device picked out and the cardiac defect repaired under direct vision, all of which were in good condition during the postoperative review. Therefore, if the ASD diameter is > 35 mm, the closure should be avoided as much as possible, as (1) A large defect easily leads to an increase in the error of evaluation of the defect diameter, resulting in an increased rate of the intraoperative umbrella, thus increasing the operation time and patient trauma, (2) A large defect is more likely to cause irregular, incomplete, or short and thin defect edge, resulting in loose closure device; thus, increasing the possibility of shedding, (3) Implantation of an oversized closure device can affect the atrioventricular conduction system and cause valve disorder, resulting in III DHS atrioventricular block or tricuspid regurgitation congruent complications.

In summary, we investigated the influence of closure directed by transesophageal echocardiography on VSD and ASD patients and observed the progress of these patients. Through postoperative review and regular follow up of 907 patients with successful closure operations, it was confirmed that the closure of VSD and ASD guided by esophageal echocardiography is safe, effective, and feasible.

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