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Evolution of surgery of ventricular septal defect closure

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Abstract

A ventricular septal defect is one of the foremost prevalent congenital heart defects, accounting for around 20% of all congenital heart malformations.

Nowadays, there are three surgical methods for ventricular septal defect: surgical treatment of ventricular septal defect with a heart-lung machine, interventional closure of ventricular septal defect by percutaneous puncture, and hybrid operation (with no heart-lung machine).

Hybrid operation – there is some of the latest evolutions introduced in cardiac surgical treatment practice. This technique is mild, to reduce surgical trauma, and perform not connecting the patient to the heart-lung machine, without X-ray exposure, and there are additional indications than the interventional procedure.

The article reviewed literature sources on the surgical treatments of the ventricular septal defect and the results of the above methods, and also considers more detail especially hybrid operation (without a heart-lung machine).

Key words: congenital heart disease, ventricular septal defect, pediatric cardiac surgery, perventricular closure technique, hybrid method

Introduction

Obstetric violence (OV), is a specific type of violatCongenital heart diseases (CHD) are the most prevalent type of birth defect. The average percentage of live-born, full-term births with CHD is in the range of 0.8% and 1% (8-10 per 1000 for full-term), while this percentage is much higher when it comes to preterm infants, which is 8.3% [1,2].

Even though there are a lot of types of CHD, which include ventricular septal defects (33%), atrial septal defects (18%), and anomalies of the pulmonary valves (10%) [3,4], in my article I will focus on VSDs due to its frequent appearance according to the abovementioned percentages. As it was mentioned before, according to the data, ventricular septal defect (VSD) is the foremost common type of congenital heart malformation. The VSDs can exist in isolation, but also it can be combined with intracardiac abnormalities, such as transposition of the great vessels, complete atrioventricular canal defects, tetralogy of Fallot, and double-outlet right ventricle. Despite the abovementioned combinations, the cause of VSD may be associated with mutations in TBX5 and GATA4 genes [5-7]. In embryonic life, the association of VSD with chromosomal defects is in the range of 10% to 30% considering it's the type and size of the defect. However, the figures can increase considering the situation after birth, depending on anatomical features of defects [8,9].

There are 4 types of ventricular septal defect:

- **Membranous VSD.** These VSDs are located in a specific zone of the upper section of the ventricular septum (a membranous septum), close to the valves. Due to the fact that this type of VSD does not close by itself, usually, it requires an operation.
- **Muscular VSD.** These VSDs are located in the muscular area of the lower section of the ventricular septum. Compared to the previous type of VSD, it is the most common type and it may close spontaneously, which leads to the situation when the operation is not necessary.
- **Atrioventricular canal type VSD.** These VSDs are combined with an atrioventricular canal defect and, there are located under the atrioventricular valves.
- **Conal septal VSD.** These types of VSDs can be considered the most uncommon type, which appears in the ventricular septum underneath the semilunar valve [10-15].

This article is based on the literature from accessible international and local scientific sources and aims to review the surgical treatment methods for isolated ventricular septal defects. Moreover, detailed information and research will be provided on the technique and the results of hybrid operation for VSD (without a heart-lung machine).

The outline of the article will include all types of surgical treatment for VSD:

1. surgical treatment of ventricular septal defect with a heart-lung machine;
2. interventional method of treatment for VSD;
3. hybrid operation for VSD without a heart-lung machine [16,17].

Surgical treatments of the ventricular septal defect

Surgical treatment of ventricular septal defect with a heart-lung machine

There are different types of treatment for VSD, surgical treatment of VSD with a heart-lung machine (HLM) could be considered the most conventional treatment modality last decades [18]. This type of treatment started to consider the gold standard after the operation by Lillehei et al. in 1954 when it VSD was closed by surgery. Although this method is effective for the treatment of VSD, the potential risks after the surgery of sequelae urged doctors and scientists for innovating [19-21]. After making research in this field and better learning of the pathophysiology of complications associated with a heart-lung machine, some improvements in the HLM technique started to appear, consequently, HLM is started to be much safer for infants. Despite the fact that the HLM technique is a satisfactory way to deal with VSD, post-HLM neurologic outcomes cannot be ignored, which would have an impact on one's quality of life, therefore, it needs to be enhanced [18].

Interventional method of treatment for VSD

Currently, with the significant development of technology and, devices surgical treatment of VSD under a heart-lung machine was not the only type of treatment for VSD. The alternative way of treatment for perimembranous and muscular VSDs is interventional closure by a percutaneous puncture. The first surgery of this type of treatment happened in 1988 and was considered a valuable and effective alternative for the selection of patients with VSD [22]. Nevertheless, this method was still linked to some negative outcomes, such as different types of arrhythmias, embolism of the occluder, and vascular complications. However, with enhancements in the device closure technique, the first real off - pump transcatheter device closure of VSD was introduced in animals in 1997 and then applied in patients with muscular VSD (mVSD) in 1998 [23]. In addition, the whole procedure is carried out under constant control fluoroscopy or transthoracic echocardiography while averting sternotomy and connecting a heart-lung machine [24].

Despite the fact this method is used for treating VSDs for relatively two decades, the sequel of prolonged fluoroscopic impact on different organs is not been sufficiently figured out by scientists. However, there are already existing side effects associated with some negative events, including arrhythmia, embolism of the occlude, and vascular complications. Moreover, as its vascular access and technical limitations, this procedure had a few problems while operating on patients with low weight or managing difficult cases, consequently, some complications (intraoperative valves abuse by wire, different types of atrioventricular block, or others) were many times reported in those cases [25].

Hybrid operation for VSD without a heart-lung machine

Initially, it is important to define this method in more detail: hybrid operation for VSD without a heart-lung machine (HLM) – a method that started to be in use only approximately the last two decades in cardiac surgery practice. According to the data published, the importance of this technique is that it allows it to perform without connecting to the HLM, additionally, no X-ray exposure and additional indications than the interventional method can be considered as different items compared to the previous methods, consequently it might minimize surgical trauma [26,27]. With the enhancement of technology and the appearance of new devices, a new type of technique was invented, by some surgeons for closing muscular VSDs [28]. The first real case practice of this surgery by perventricular closure of VSD was fulfilled on animals under the control of transesophageal echocardiography (TEE) in 1997. Based on the experience Amin and his colleagues performed this type of closure of VSD on patients in 1998 [29,30]. Moreover, scientists always tried to find a different way of incision for VSD, consequently, Bacha and his coworkers reported the case when the operation on a patient who had muscular VSD was done with the usage of subxiphoid access in 2003. The abovementioned case was considered the first case when muscular VSD was treated without HLM by subxiphoid access. There was no reported case of hybrid closure of perimembranous VSD without HLM in patients through subxiphoid access before 2006 [31]. In that year, Doctor Li Feng recomended the closure of perimembranous VSDs without HLM in patients by subxiphoid access in China. Even though long-term side-effects have not been reported, it showed a good result in the short period. Important to mention here is that the technique was used in the 12 patients and all cases have finished effectively [32].

In comparison with previous surgical methods - winding track through the blood vessels of the thigh in the interventional method or post-HLM neurologic outcomes after the traditional operation, the last method has more direct access to VSD, without HLM, which is a more secure way for patients [33].

Based on statistics provided by reliable articles reported work average mortality of the hybrid method is lower than that of surgical treatment. For example, the mortality after the hybrid method is 2.6%, this is 3 in 116 cases with isolated mVSD, and also 24.1% of the cases with multiple mVSDs. The mortality after surgical treatment is more than in the above method. This is 3.6% (2 in 56 cases with isolated mVSD) and 17% with multiple mVSDs. Moreover, based on other statistics provided by researchers, comparable mortality was indicated in the interventional method (10.6%, 6 in 55 cases, 22 cases with single mVSD) [34-36].

Furthermore, ventricular dysfunction was a case that should be considered. According to several cohort studies of multiple mVSDs the ventricular dysfunction had more after surgical treatment than the hybrid method. For instance, after five years of follow-up left ventricular dysfunction rate of 30% after a left ventriculotomy (after surgical treatment) [37-39], as the hybrid method had less left ventricular dysfunction, ranging from 7.1% to 12.5%, which was reclaimed after 3 years. Also, the right ventricular dysfunction rate (after surgical treatment) varied from 0% to 22% [41-43], and after hybrid method had not to case about the right ventricular dysfunction [40,44].

As it was mentioned before, there have not been fulfilled long-term studies on this method of surgical treatment, but there are short- and medium-term studies with the conclusion that serious functional problems are limited. Additionally, it was reported that if the treatment was performed at early ages,

quality of life will not have significant changes compared to normal life [45].

Moreover, it is important to report the experience of our medical center – the National Scientific Medical Center, which is located in Nur-Sultan, Republic of Kazakhstan. The hybrid method has been implemented by professor Xiangbin Pan from China in 2016. From 2016 to 2022 operations were performed on more than 400 patients, which is an excellent and leading result among all Kazakhstan's medical centers. Currently, we are doing a retrospective study for evaluating the effectiveness and safety of this method. Further, the results based on these patients will be published in an original research article that will be written by me and my colleagues.

Table 1 Perioperative and postoperative performance indicators of three surgical treatments for VSD [51-53].

Indicators	**Surgical treatment of VSD with a heart-lung machine**	**Interventional method of treatment for VSD**	**Hybrid operation for VSD without a heart-lung machine**
Access	total median sternotomy	vascular access	partial sternotomy
Wound size	depend on the size of the sternum (from 5 cm and more)	0.35-0.5cm	2-4 cm
Optimal body weight for surgical repair	from 4 kg	from 10 kg	from 4 kg
The heart-lung machine time (min)	56.6 ± 13.5	0	0
Aortic occlusion clamping time (min)	39.1 ± 12.3	0	0
Mechanical ventilation time (h)	15.8 ± 4.8	0	10.5 ± 2.8
Intensive care unit time (h)	22.6 ± 5.8	0	13.7 ± 2.5
Radiation	no	yes	no
The average length of surgery (min)	60-100	20-40	30-60
The average length of stay in a hospital (days)	7-10	3	5-7
Complications after surgical repair:			
- residual shunt	2-3%	1-2%	2-3%
- atrioventricular block	0	1%	1-2%
- right bundle branch block	0	1%	1%
-new tricuspid regurgitation	0	1-2%	1-2%
-new aortic regurgitation	0	1-2%	1-2%
-incision complications	2-3%	0	0
-pericardial effusion	2-3%	1%	0
-pneumothorax	1%	0	0

Surgery steps of hybrid method

The technique of the hybrid method is comparable with the interventional method except for its direct access to the defect. The general steps of the hybrid method are described below and in Figure 1 [46-48].

Step 1: Firstly, preoperative assessment, then it is necessary to use general anesthesia. Before the surgery, transesophageal echocardiography (TEE) should be used to evaluate the location and morphology of the VSD, with special emphasis paid to any concurrent valve dysfunction.

Step 2: The delivery mechanism is being prepared. The device that is appropriate for the defect is selected and the delivery system, which adds a device cable, delivery sheath, sheath for loading, and guidewire, is also assembled (Figure 1A).

Step 3: Starting with a transthoracic incision, the size of the wound is from 2 to 4 cm and then lower median sternotomy is recommended. Also, there is another incision - anterior parasternal incision for sub arterial VSDs (Figure 1B).

Step 4: After sternotomy uncovers the pericardium and then selects the anterior free wall of the right ventricle for puncture under control transesophageal echocardiography (Figure 2A).

Step 5: Then, the delivery mechanism is introduced. To do this, a purse-string suture is used on the free wall of the right ventricle facing the location of the defect chosen (Figure 2B), a 6F gauge needle is imported through the purse-string suture, and the guiding wire is inserted into the right ventricle (RV) and then through the defect to the left ventricle (LV) (Figure 2C). A delivery sheath is led into the LV over the guidewire (Figure 2D).

Step 6: Under transesophageal echocardiography on the beating heart the device is deployed. At first, the left ventricular disc is expanded and deployed to the septum with a guidewire (Figure 2E), and then the right ventricular disc is subsequently deployed to begin closing the ventricular septal defect (Figure 2F and G).

Step 7: Prompt postoperative appraisal. After the accomplishment of device placement, transesophageal echocardiography is done for detecting any valve dysfunctions or residual shunts [49,50].

Figure 1 - The delivery mechanism for hybrid method (1A) and surgical incision options (1B).

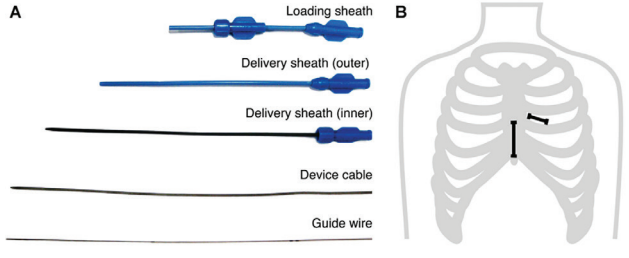
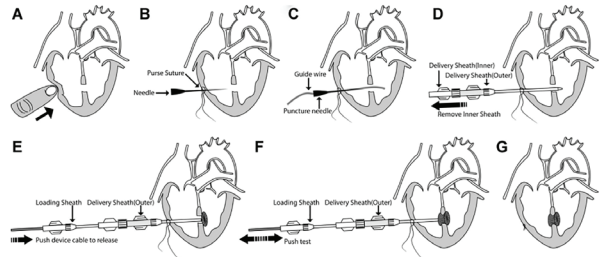


Figure 2 - General steps of the hybrid method.



Conclusion

The hybrid operation for ventricular septal defect without a heart-lung machine is plain, and effective which accompanies minimal surgical trauma, and relatively safeguard options for selected patients with isolated VSD, in contrast to the classical method.

The hybrid operation not only reduces the risk of significant complications and blood product transfusion, but also shortens the duration of hospitalization, and rehabilitation compared with the traditional method with a heart-lung machine but also produces no inferior results compared with the interventional method in selected isolated VSD patients. Moreover, this method is technically not a complex operation compared to the traditional method, in order to know the full potential of this method as the new gold standard of surgical treatment, controlled studies with long-term follow-up are needed.

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