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ECHOCARDIOGRAPHIC FOLLOW-UP POST VENTRICULAR SEPTAL DEFECT CLOSURE

Abd Almohsen A. M.[1], Allam A. R.[2], Eldomiati A. M.[1]*, Sabah M. H.[1] and Antonios A. M.[1]

[1]Department of Pediatrics-Faculty of Medicine - Alexandria University, Egypt.
[2]Department of Cardiothoracic Surgery-Faculty of Medicine-Alexandria University.

***Corresponding Author: Eldomiati A. M.**
Department of Pediatrics-Faculty of Medicine - Alexandria University, Egypt.

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ABSTRACT

Background: The most common form of congenital heart disease in childhood is the ventricular septal defect (VSD), occurring in 50% of all children with congenital heart disease and in 20% as an isolated lesion. The size of the VSD, the pressure in the right and left ventricular chambers, and the pulmonary resistance are factors that influence the hemodynamic significance of VSDs. Left-to-right shunting in VSDs generally increases pulmonary arterial blood flow and pulmonary venous return to the left heart. These pathophysiologic sequels may result in volume overload of the left atrium and left ventricle, and subsequent left ventricular enlargement, mitral annular dilation, mitral regurgitation, and consequent left atrial enlargement to allow for the homeostatic balance of left atrial pressure. **Aim:** The aim of the work is to assess the extent of improvement of LV dimensions after surgical closure of VSD. **Methods:** This prospective non controlled study was conducted on 30 children with isolated congenital ventricular septal defect after the surgical closure of VSD. All patients were brought for follow up visits where transthoracic echocardiography repeated immediately after surgery and at 3 and 6 months postoperative for assessment of adequacy of VSD closure, improvement of left sided dimensions and residual mitral regurge. **Results:** The current study showed that mean age of studied patients was 22.9 +/-29 months. About 17 were females, and 13 were males. Sixty eight percent had perimembranous VSD, 13% had muscular VSD, 10% had inlet VSD and 10% had outlet VSD. Eighty percent of our patients had no MR, 13% had mild MR, 7% had moderate MR. There was significant increase in ejection fraction in postoperative follow-up echocardiography. There was significant progressive reduction in left ventricular end diastolic diameter and end systolic diameter in 3 and 6 months follow up echo studies. Degree of mitral regurgitation did not significantly decreased post- surgery. **Conclusion**: Surgical closure of VSD in infancy results in improvement of left ventricular ejection fraction and reduction of left ventricular dimensions.

KEYWORDS: Ventricular septal defect, echocardiography, diagnosis, surgical closure.

1. INTRODUCTION

Ventricular septal defect (VSD) is the most common congenital heart disease in children and is an important risk factor for the substantially increased morbidity and mortality in children. It is a developmental defect of the inter- ventricular septum resulting from a deficiency of growth or a failure of alignment or fusion of component parts of ventricular septum. VSD appears either as an isolated cardiac defect without other abnormalities or with several complex malformations. While many VSDs close spontaneously, if they do not, large defects can lead to detrimental complications such as pulmonary arterial hypertension (PAH), ventricular dysfunction and an increased risk of arrhythmias.[1-3]

VSDs were first clinically described by Roger in 1879, the term maladie de Roger is still used to refer to a small asymptomatic VSD.[4]

In 1898, Eisenmenger described a patient with VSD, cyanosis, and pulmonary hypertension. This combination has been termed the Eisenmenger complex. Pulmonary vascular disease and cyanosis in combination with any other systemic-to-pulmonary connection has been called the Eisenmenger syndrome.[5]

Isolated VSD accounts for 37% of all congenital heart disease in children. The incidence of isolated VSD is about 0.3% of newborns. Because as many as 40% may eventually close spontaneously; the incidence is significantly lower in adults. VSDs have no gender predilection.[6] The incidence of VSD has increased dramatically with advances in imaging and screening of infants ranging from 1.3 to 17.3 per 1000 live births.[7]

The natural history of VSD has a wide spectrum, ranging from spontaneous closure to congestive heart failure (CHF) to death in early infancy. Spontaneous closure frequently occurs in children by the age of 2 years. Closure is uncommon after age of 4 years.[8]

Closure is most frequently observed in muscular defects (80%), followed by peri-membranous defects (35-40%). Outlet VSDs have a low incidence of spontaneous closure, and inlet VSDs do not close.[9]

Long term results of VSD repair are favorable. In the absence of pulmonary vascular disease, infants who undergo VSD repair within the first 1-2 years of life are considered cured and demonstrate improved physical development (growth and weight gain), as well as normal long term ventricular function. Most long term survivors are asymptomatic and lead normal lives. Exercise tolerance may be diminished. If congestive heart failure and cardiomegaly are well established and repair has been undertaken late in life, postoperative symptoms, including exercise intolerance, are more common. Premature late death is rare (less than 2.5%) in patients with low preoperative pulmonary vascular resistance. Patients with preoperative pulmonary vascular disease may develop severe, life threatening pulmonary hypertension.[10,11] The current surgical mortality is less than 2% for isolated VSD.[12]

2. SUBJECT AND METHODS

A prospective non controlled study was conducted on 30 children with isolated congenital ventricular septal defect after the surgical closure of VSD.

All patients were brought for follow up visits where transthoracic echocardiography repeated immediately after surgery and at 3 and 6 months postoperative.

- Initial clinical examination for exclusion of associated complications that would compromise left ventricle (LV).
- Initial and follow-up echocardiographic studies to assess the following:

a- Mitral valve
b- LV dimensions and functions.
c- Surgical patch leaks.
d- Pericardial effusion.
e- Assess pulmonary pressure.
f- Left atrial dimensions.

3. RESULTS

In the present study, 56.67% of patients (n=17) were females, and 43.33% (n=13) were males. The age ranged from 7.00 to 132.00 months with a median (IQR) 14.50 (11.00-18.00) months. Nine (30.00%) patients were aged less than 12 months, 15 (50.00%) patients aged 12-24 months, 4 patients (13.33%) aged 24-72 months and 2 (6.67%) patients aged more than 72 months. The weight ranged from 5.00 to 35.00 kg with a median (IQR) 9.25 (8.40-10.00) kg. (Table I).

Table (I): Demographic data of the study group according to gender.

	No (%)
Sex	
- Male	13 (44.33%)
- Female	17 (56.67%)
Age (months)	
- n	30
- Min-Max	7.00-132.00
- Median (IQR)	14.50 (11.00-18.00)
Age (months)	
- 1-<12	9 (30.00%)
- 12-<24	15 (50.00%)
- 24-<72	4 (13.33%)
+ 72	2 (6.67%)
Weight (kg)	
- n	30
- Min-Max	5.00-35.00
- Median (IQR)	9.25 (8.40-10.00)

n : Number of patients Min-Max: Minimum – Maximum IQR: Inter-quartile range.

The size of VSD ranged from 3.00 to 13.50 mm with a median (IQR) 7.35 (6.00- 8.50) mm. The pressure gradient across VSD ranged from 15.00 to 100.00 mmHg with a median (IQR) 17.00 (15.00-35.00) mmHg. Twenty six (86.67%) patients had perimembranous VSD, 4 (13.33%) had muscular VSD, 3 (10%) had outlet and 3(10%) had inlet VSD. Patient may have more than one type of VSD, in the present study 2 patients had outlet and perimembranous type, 3 patients had inlet and perimembranous and 1 patient had muscular outlet type. (Table II).

Table (II): Descriptive data of the Pre-surgery echocardiographic findings.

	n=30
Size of VSD (mm)	
- Min-Max	3.00-13.50
- Median (IQR)	7.35 (6.008.50)
Pressure gradient (mmHg)	
- Min-Max	15.00-100.00
- Median (IQR)	17.00 (15.00-35.00)
Types of VSD	
- Peri-membranous	26 (86.67%)
- Muscular	4 (13.33%)
- Inlet	3 (10.00%)
- Outlet	3 (10.00%)

n : Number of patients Min-Max: Minimum – Maximum IQR: Inter-quartile range.

Twenty one (70%) patients had mild degree of left ventricular dilatation before surgery at 3 months 7 patients improved and 14 (46.67%) patients had mild degree of dilatation and at 6 months after operation 2 patients improved and 12 (40%) patients had mild dilatation. Five (16.67) patients had moderate degree of LVD before surgery at 3 months 4 patients improved and 1(3.33%) patients had mild degree of dilatation and at 6 months improved. There was statistically significant improvement in the number of patients (proportions) having no or mild LV dilatation by time (T=7.000, p=0.030) (Table III).

Table (III): Pre-surgical and follow-up echocardiography as regard left ventricular dilatation.

LVD	Before surgery	3 months after operation	6 months after operation
No - **n** - **%**	4 13.33%	15 50.00%	18 60.00%
Mild - **n** - **%**	21 70.00%	14 46.67%	12 40.00%
Moderate - **n** - **%**	5 16.67%	1 3.33%	0 0.00%
Total - n - %	30 100.00%	30 100.00%	30 100.00%
Cochran's Q test	T(df=2) =7.000 *p*=0.030*		

n : Number of patients df: degree of freedom *: Statistically significant (p<0.05).

The LV end diastolic dimension pre- surgery ranged from 17.60-40.00 mm with a median (IQR) 23.20 (17.60-35.00). The same dimension 3 months after operation ranged from 11.00-35.00 with a median (IQR) 22.10 (17.60-31.00), and after 6 months post-surgery, it ranged from 11.00-32.00 with a median (IQR) 22.00 (17.60-28.00). (Table VII). The end diastolic dimension statistically decreased during the different time of measurements (□^{2}=47.043, *p*=<.001). (table IV) (Figure 1).

Table (IV): Presurgical and follow-up echocardiography as regard LVEDD.

	n=30
LVEDD (Before surgery) - Min-Max - Median(IQR)	17.60-40.00 23.20[a] (17.60-35.00)
LVEDD 3 months after operation - Min-Max - Median(IQR)	11.00-35.00 22.10[b,c] (17.60-31.00)
LVEDD 6 months after operation - Min-Max - Median(IQR)	11.00-32.00 22.00 [b,c] (17.60-28.00)
Test of significance	□^{2}(Fr)(df=2)=47.043 *p*=<.001*

n : Number of patients LVEDDD: left ventricle end diastolic dimension Min-Max: Minimum - Maximum IQR: Inter-quartile range Fr: Friedman test * : Statistically significant (p<0.05).

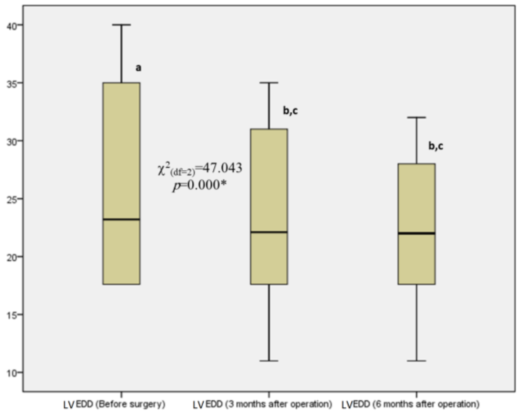

Figure (1): Box and whisker graph in the studied group as regard LVEDD, the thick line in the middle of the box represents the median, the box represents the inter-quartile range (from 25th to 75th percentiles), and the whiskers represent the minimum and maximum. *Different superscript letters indicate statistical significant using Dunn-Sidek method.*

The LV end systolic dimension before surgery ranged from 11.20-28.00 with a median (IQR) 14.20 (11.20-21.00). The same dimension 3 months after operation ranged from 11.00-23.00 with a median (IQR) 12.75 (11.00-14.20) and at 6 months after surgery, it ranged from 8.00-21.00 with a median (IQR).

11.20 (11.00-14.00). The LV end systolic dimension statistically decreased during the different time of measurements (□^{2}=50.317, *p*=<.001). (table V) (Figure 2).

Table (V): Presurgical and follow-up echocardiography as regard LVESD.

	n= 30
LVESD (Before surgery)	
- Min-Max	11.20-28.00
- Median(IQR)	14.20^{a} (11.20-21.00)
LVESD (3 months after operation)	
- Min-Max	11.00-23.00
- Median(IQR)	12.75^{b,c} (11.00-14.20)
LVESD (6 months after operation)	
- Min-Max	8.00-21.00
- Median(IQR)	11.20 ^{b,c} (11.00-14.00)
Test of significance	^{2}(Fr)(df=2)= 50.317 *p*=0.000*

n : Number of patients Min-Max: Minimum – Maximum IQR: Inter-quartile range Fr: Friedman test
* : Statistically significant (p<0.05).

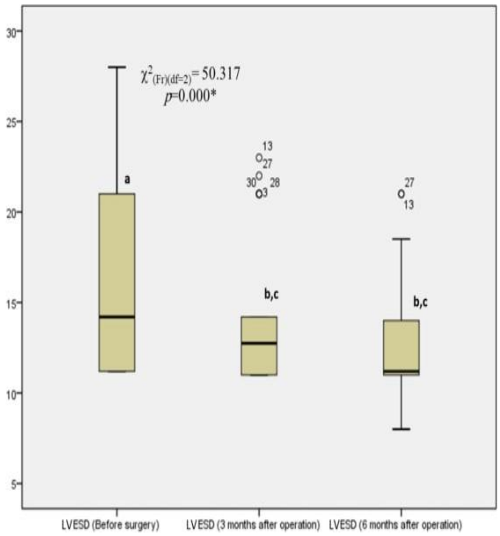

Figure (2): Box and whisker graph in the studied group as regard LVESD, the thick line in the middle of the box represents the median, the box represents the inter-quartile range (from 25th to 75th percentiles), and the whiskers represent the minimum and maximum after excluding outliers (black circles). ***(Numbers indicate serial number of the patient in the original master table) Different superscript letters indicate statistical significant using Dunn-Sidek method.***

The ejection fraction (EF) before surgery ranged from 53.90-75.00 with a median (IQR) 64.00 (62.00-65.00). The EF 3 months after operation ranged from 54.00-75.00 with a median (IQR) 64.00 (62.00-65.00). The EF (6 months after surgery) ranged from 54.00-75.00 with a median (IQR) 65.00 (62.00- 68.00). The EF statistically improved during the different time of measurements (□^{2}=18.092, *p*=<0.001). (table VI)(Figure 3).

Table (VI): Pre-surgical and follow-up echocardiography as regard EF.

	n= 30
EF (%) (Before surgery)	
- Min-Max - Median(IQR)	53.90-75.00 64.00^{a,b} (62.00-65.00)
EF (%) (3 months after operation)	
- Min-Max - Median(IQR)	54.00-75.00 64.00^{a,b,c} (62.00-65.00)
EF (%) (6 months after operation)	
- Min-Max - Median(IQR)	54.00-75.00 65.00^{b,c} (62.00-68.00)
Test of significance	□^{2}(Fr)(df=2)=18.092 *p*=0.000*

n : Number of patients Min-Max: Minimum – Maximum IQR: Inter-quartile range
Fr: Friedman test *Different superscript letters indicate statistical significant using Dunn-Sidek method*
* : Statistically significant (p<0.05).

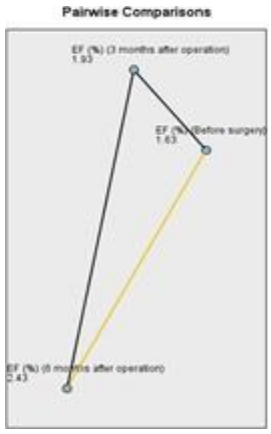

Figure (3): Pairwise comparison between TTE of presurgical EF and follow-up EF.

Twenty four patients (80%) before surgery had no MR and 4 (13.33%) patients had mild degree MR and showed no decrease in the degree of MR in the follow-up post-operative echocardiography, while 2 (6.67%) patients had moderate degree MR before surgery 1 patient continued with mild degree MR and the other patient decreased to mild degree MR at 6 months follow-up echocardiography. There was no statistically significant change in the proportion of MR grades with different time after operation (T=2.000, p=0.368) (Table VII).

Table (VII): Comparison of pre-surgical and follow-up echocardiography as regard MR.

MR	Before surgery	3 months after operation	6 months after operation
No			
- n	24	24	24
- %	80.00%	80.00%	80.00%
Mild			
- n	4	4	5
- %	13.33%	13.33%	16.67%
Moderate			
- n	2	2	1
- %	6.67%	6.67%	3.33%
Total			
- n	30	30	30
- % total	100.00%	100.00%	100.00%
Cochran's Q test	T(df=2) =2.000 *p*=0.368 NS		

n : Number of patients X^2 = Pearson Chi-Square df: degree of freedom NS: Statistically not significant ($p \geq 0.05$).

4. DISCUSSION

In the present study, most patients had preoperative high left ventricular end diastolic diameter (LVEDD), there was highly significant reduction in LVEDD in patients in all age groups due to restoration of hemodynamics in the form of decrease in the preload and afterload after removal of shunt burden, This is in agreement with the study by Zheng et al., (2007)[13] who showed that trans-catheter preoperative values for LVEDV were elevated in 30 VSD patients, it significantly decreased on the 3rd and 6th month after the VSD closure. The results of the present study is also in agreement with the study by Abdelaziz et al., (2016)[14] who studied the effect of corrective surgery on left ventricular ejection fraction, left ventricular and atrial dimensions in 60 children with VSD, where preoperative LVEDD significantly decreased after surgical closure of the VSD. The study of Ross-Hesselink et al., (2004)[15] found the left ventricular dimensions were normal in 96% of patients as they followed up 176 consecutive patients 20-34 years after surgical closure of isolated VSD which was done at young age. Similar results were also found by Cho et al., (2014)[16] who evaluated the effect of severity of MR on the speed of improvement of echo parameters after VSD closure on 40 patients, the reduction in LVEDV was associated with the severity of MR; where the no MR group showed no significant decrease in the LVEDV index, at any time following closure of the VSD. The mild MR group demonstrated a significant reduction in the LVEDV index at one month, three months, and 12 months postoperatively. The moderate to severe MR group demonstrated a significant reduction in the LVEDV index only at 12 months postoperatively. The results of the present study were also in agreement with the study by Pawelec et al., (2005)[17] who showed significant reduction in the left ventricular diameter after closure of peri-membranous VSD either by catheter or by surgery, the study was carried on 11 children treated with peri-membranous VSD occlude implantation and 12 children with surgical repair. In the present study, there was postsurgical significant increase in ejection fraction 6 months after surgery in most patients. This could be attributed to improvement of hemodynamics, reduced volume overload and reverse remodeling as ejection fraction is a useful parameter for measuring cardiac performance, as preload tends to elevate the ejection fraction. The presence of both increased preload, (i.e. LVEDV), and decreased afterload, via ejection across the VSD into the pulmonary circuit, likely contribute to the normal preoperative values for EF in our patients. Following closure of the defect, both preload and after load tend to normalize and any intrinsic depression of left ventricular function should become manifest as an abnormally low ejection fraction. These results are in agreement with study by Aminullah et al. (2016).[18] where left ventricular ejection fraction (LVEF), fractional shortening, left ventricular internal diameter during diastole (LVDDd) and left ventricular internal diameter during systole (LVIDs) significantly improved after 3months of surgery. The presence of decreased left ventricular contractility in postoperative VSD patients may be due to the diffuse cardiac sclerosis in various forms of congenital heart disease (including VSD), it could be suggested that the better functional status is related to the shorter length of time that their hearts were subjected to abnormal work requirements. Other factors should be considered; perhaps the major one is operating room procedure: operative technique has changed considerably over the past decade with far greater appreciation being given to the possible permanent effects of myocardial ischemia produced during intra-cardiac manipulation. Patients in the present study had their defects closed using cardiopulmonary bypass and surface cooling with intermittent cross-clamping of the aorta. It is conceivable that the intraoperative procedures used served to protect their hearts to a greater degree than was possible ten years ago, old methods of cardioplegia and the long time taken to perform the surgery and this factor contributed to the better functional results. Another factor that should be considered is the lack of hypertrophy as compared to dilatation.

In the present study the degree of MR was not significantly decreased post-surgery. Three months postoperative echo showed no significant decrease in the degree of MR where 80% had no MR, 13.3% had mild MR and 6.7% had moderate MR. Six months post-operative echo also showed no significant decrease in degree of MR where 80% had no MR, 16.7% had mild MR and 3.3% had moderate MR. The results of the present study is in agreement with the study by Ross-Hesselink et al., (2004).[15] who reported no significant change in MR. The results of the present study are not in agreement with the study by Cho et al., (2014).[16] who showed that the group which did not have MR preoperatively did not progress to new-onset MR after surgical closure of the VSD, All patients improved regarding the degree of MR. this can be attributed to reduction in LV volumes and reduction of mitral annular dilatation degree. The results of the present study are also not in agreement with the study by Pawelec et al., (2005)[17] who showed that MR decreased significantly after closure of VSD with the membranous VSD.

This study is not without limitations. First, this was a single center study and results could not be generalized. Second, the relatively short duration of follow- up where significant morbidities or improvement could not be ascertained. Even with these limitations, the study provides important preliminary data that can be used for more prolonged and multicenter studies.

5. CONCLUSION

Surgical closure of VSD in infancy results in improvement of left ventricular ejection fraction and reduction of left ventricular dimensions, and this was shown with all degrees of preoperative mitral regurgitation.

Conflict of interest and financial support

All authors of this article declare no conflict of interest and all of them declare that they did not receive any financial support.

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