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Comparative study between results of using synthetic versus pericardial patches for VSD closure in infants and children

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***Abstract*---**Background: Generally ventricular septal defects (VSDs) are repaired with synthetic material: either Dacron (polyethylene terephthalate) or Goretex (expanded polytetrafluoroethylene) depending on surgeons preference. Aim of the work: To compare between the outcome of VSD closure by synthetic patches versus pericardial patches. Patients and methods: This study was conducted on 60 patients with surgical VSD closure. They were divided into 2 groups each included 30 patients. In group I synthetic patch (Dacron or Gortex) was used. In group II pericardial patch (fresh or treated or bovine) was used. The patients were evaluated at 3m and 6m after operation for: residual defects, endocarditis, heart block, AR, TR, LV dimensions and function and any other complications. Results: Ventilation time, was statistically significant shorter in group II (8.53 ± 6.37h) compared with Group I (30.60 ± 20.84h) p value 0.001*. Statistically significant shorter ICU time was found in group II (2.53 ±

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0.90d) compared with group I (3.70 ± 1.62d). Twenty (66.7%) patients and 28(93.3%) patients in group I and II respectively had sinus rhythm. While 10 (33.3%) patients and 2 (6.7%) patients in group I and II respectively had temporary heart block. residual VSD was found in 8(26.7%) patients in group I and no patient in group II showed residual VSD with statistical significant difference. Conclusion: Pericardial patch is easily available, sterile, and non-immune reaction. The handling characteristics of fresh or glutaraldehyde-treated autologous pericardium are better than other materials with lower incidence of post-operative arrhythmias and residual VSD.

Keywords---VSD, surgery, synthetic patch, pericardial patch.

Introduction

Roger published the first clinical description of ventricular septal defects (VSDs) in 1879; a minor, asymptomatic VSD is still referred to as a "Maladie de Roger." Eisenmenger documented a patient in 1898 who had pulmonary hypertension, cyanosis, and VSD. The Eisenmenger complex has been used to describe this combination. The Eisenmenger syndrome is characterised by cyanosis and pulmonary vascular disease in addition to any other systemic-to-pulmonary link [1, 2]. The second most frequent congenital abnormality in adults, behind a bicuspid aortic valve, is a VSD, which is the most common congenital cardiac anomaly in children. Dalrymple made the initial discovery of it in 1847 [3]. VSD is characterised by improper right-to-left ventricular communication, and the main mechanism causing hemodynamic compromise in VSD is shunt development [4]. Large defects can cause harmful sequelae such pulmonary arterial hypertension (PAH), ventricular dysfunction, and an elevated risk of arrhythmias even though many VSDs repair spontaneously [5].

According to the surgeon's preference, synthetic materials such as Dacron (polyethylene terephthalate) or Goretex (expanded polytetrafluoroethylene) are typically used to repair VSDs. In the early postoperative phase, an echocardiography frequently detects small residual VSDs that can be sealed off by dacron by inducing a fibrous reaction [6]. For VSD closure, both autologous and xenograft (bovine, equine) pericardium may be employed. Fresh pericardium that hasn't been treated is tough to handle and over time has the potential to shrink and stretch. According to Schoof et al. [7], intra-operative patch oversizing as well as the use of fresh autologous pericardial patches can both contribute to aneurysm formation. Aim of the work was to compare between the outcome of VSD closure by synthetic patches versus pericardial patches.

Patient and Methods

Patients

This was retrospective, comparative, randomized study included patients who had congenital heart disease in the form of ventricular septal defect and candidate for surgical closure of VSD. The patients were recruited from Cairo University affiliated hospitals in the period from March 2018 to March 2020.

The patients were divided into two groups

- **Group I** included 30 patients who had surgical VSD closure using synthetic patches either Gortex or Dacron.
- **Group II** included 30 patients who had surgical VSD closure using pericardial patches either xenopericardium or auto pericardium (fresh or glutaraldehyde treated).

Inclusion criteria

- Patients (Infants and children with age from 3m to 12y of both sex) with CHD, VSD indicated for surgical closure whether primary or Post band cases.
- Patients with VSD associated with simple congenital heart defects as ASD or PDA.

Exclusion criteria

- Patients with VSD associated with other complex congenital heart disease.
- Data of the patients a were reviewed and collected from medical files at the registry of cardiothoracic surgery unit, post-operative cardiothoracic surgery ICU and outpatient clinic Cairo university affiliated hospitals.

Methods

Data collected included the following
Preoperative parameters

- Anthropometric data: age and sex and weight.
- Echocardiographic data:
  - Type and size of VSD.
  - Presence of LV dilatation and its degree.
  - Presence of pulmonary hypertension and its degree.
  - Degree of TR.
  - Presence of aortic cusp prolapse and AR.
  - Cardiac functions (EF and FS).

Anesthesia Management Premedication

Patients were premedicated by Intramuscular Midazolam (0.2mg/kg), atropine (0.01 mg/kg) and Ketamine (2 mg/kg) 20 minutes before induction of anesthesia. All patients had inhalational induction using sevoflurane in a mixture of oxygen and air after placement of standard monitors, including electrocardiogram (ECG), pulse oximetry (Spo2), and non-invasive blood pressure cuffs. This was followed by implantation of a peripheral intravenous cannula. The intravenous injection of fentanyl (2-4 g/kg) and pancuronium (0.1 mg/kg) assisted oral endotracheal intubation. In all patients, a central venous line, an urine catheter, and an intra-arterial line were placed, either in the radial or femoral artery. All patients were receive mixture of sevoflurane 1%-4% in oxygen aiming to maintain mean arterial blood pressure and heart rate within 20% of the base line values and targeting Bispectral index (BIS) of 40–60. Boluses of Pancuronium 0.01mg/kg/hr was given for maintaining neuromuscular blockade. Fentanyl in a dose of 2mcg/kg was administered at the time of skin incision, sternotomy, pericardial opening, and the cannulation time and on cardiopulmonary bypass (CPB) not exceeding total dosage of 15-20 mcg/Kg. ventilation was mechanically controlled using pressure mode to maintain PaCO2 between 30 and 35 mmHg.

Operative parameters

- Type of patch, tech of suturing whether interrupted or continuous.
- Ischemic time.
- Bypass time.
- Patients required inotropic support in each group.
- Patients rhythm.
- Total operative time.

Operative procedure
Surgical exposure and cannulation

The patients were placed in supine position. All patients are approached via median sternotomy. In primery patients (1st go patients) the thymus gland was dissected and the pericardium was opened vertically or inverted T shaped. Stay sutures by heavy silk suturing the pericardium to the edges of the incision usually give adequate exposure. In redo patients (post band) certain precaution were taken as presence of packed RBCs in theater, making sure CPB is ready before initiating the procedure. carful sternotomy and dissection of pericardial adhesion was done using both sharp and blunt dissection. Aorto-bicaval cannulation was done using approproiate sized cannulae according to the body surface area of each patient

Surgical technique

All patients were conducted to cardiopulmonary bypass (CPb). In All Primary patients in this study, PDAs were dissected or ligated if present. Patients with previous pulmonary artery banding, Dissection was done around the band and the tape of the band was cut, and removed from the PA at that stage. If not easily dissected, it was left till the patient was on cardiopulmonary bypass (CPP) and cardioplegia given. The band was dissected and removed at that time and hegar dilator was passed to dilate the pulmonary artery at the site of the band. Myocardial protection was achieved by infusion of cold cardioplegia whether blood based cardioplegia or crystalloid cardioplegia. Induction dose is 30 ml/kg over 3-5 min followed by maintenance dose of 20 ml/kg every 30 min through cardioplegia canula in aortic root. Lt ventricular venting was achieved by canula in rt sup pulmonary vein in cases of transaortic repair and through PFO in transatrial repair. The VSD was approached through: (a-) Oblique aortotomy in cases with subaortic VSD and aortic cusp prolapse especially if aortic regurge is present to perform aortic cusp resuspension through the same route. (b-) Right atriotomy in other types of VSD (perimembranous outlet, inlet, muscular VSD) exposure of VSD through suspension sutures in the Tricuspid leaflets no case was approached through either pulmonary artery, right ventricle or left ventricle.

In group I

- VSD closure was performed using synthetic patch either gortex or Dacron.
- The continuous suture technique was used to close every wound. Depending on the size of the youngster, sutures made of polypropylene in 5.0′ or 6.0′ gauge were utilised. At the anterior and inferior edges of the defect, a double-armed mattress suture reinforced with pledgets was used as the first stitch. The lower margin of a patch with the proper configuration was then punctured with the needles. In order to stabilise the patch and the suture, the patch was lowered into the defect, pushed into the VSD, and connected to three knots. The septal muscle and patch were then bitten into with one arm of the suture as it was moved along the anterior margin of the defect until it reached the annulus of the tricuspid valve at the anterior and superior boundary. Here, the suture turns by biting into the patch with a mattress suture and then passing through the tricuspid valve annulus to exit on the right atrial side. This suture arm is placed aside after being secured in a rubber-soled mosquito clamp. The inferior and posterior edges of the defect were then stitched with the other arm of the suture. These suture bites were made 4-5 mm away from the margin and toward the rear.
- In order to avoid the conduction system near to the annulus of the tricuspid valve, margin is reached when these bites are made shallower than the previous bites. This suture was likewise rotated as it got close to the tricuspid valve annulus on the posterior margin, just like it did at the anterior margin, by taking a small bite on the patch and then passing through the base of the septal leaflet. As a result, the suture exits on the right atrial side, much like the one at the anterior edge. This thread was then used as a mattress suture, weaving alternately through a strip of pericardium, the patch, and the base of the septal leaflet to strengthen the suture line and prevent dehiscence. Up until the two meet, the labelled suture at the anterior margin is similarly weaved through the pericardium, leaflet tissue, and patch. After that, the sutures were secured. The tricuspid valve chordae were dealt with along the suture line by wrapping the suture around the structure and seating the patch so that the chord was on the right ventricular side of the patch. It may be more challenging to weave around a group of chordae that are near to the posterior boundary; in these cases, the patch would be sliced at the location of the chordal attachment. As a result, the patch would be firmly in place around the chordae, and if necessary, interrupted sutures were placed at the location of the patch's slit.

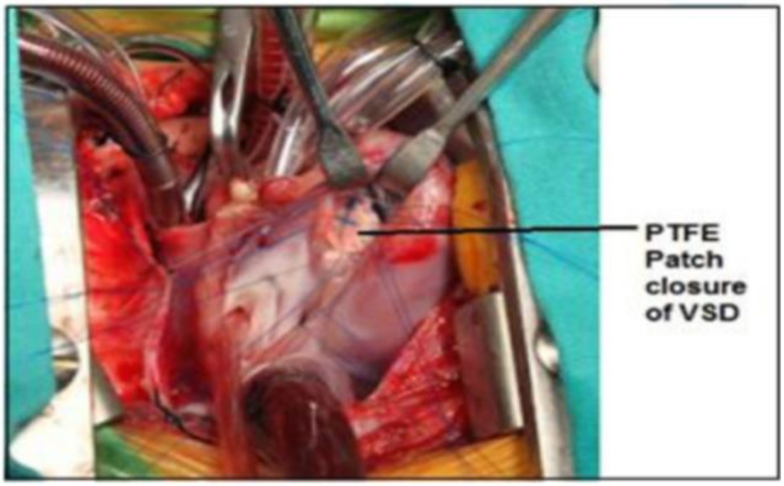

Figure 1. VSD closure by PTFE patch by continuous sutures

In group II

- VSD closure was done using either fresh autopericardium, gluteraldhyde, treated autopericardium or preserved bovine pericardium.
- A free pericardium graft was taken, being careful to spare the phrenic nerves damage. To prevent creases, it was stretched out on sterile, hard cardboard sheets. After 20 minutes of treatment with 0.6% glutaraldehyde solution, it was three times rinsed in 0.9% saline for 5 minutes.
- The pericardial patch was cut to fit the VSD's dimensions. Using 5/0 polypropylene continuous suture, the defect was repaired with a pericardial patch, avoiding damage to the aortic cusps by working from the inferior margin up toward the anterosuperior margin and superiorly into the aortic valve. The posteroinferior margin was closed all the way to the tricuspid valve's septal leaflet using the second arm of the suture. A strip of pericardium was used as reinforcement to seal the tricuspid edge of the defect. When utilising interrupted sutures, pledget-supported interrupted mattress sutures were first positioned all the way around the defect's edges, then they were passed through an approximately fitted patch and lowered down before being tied in.

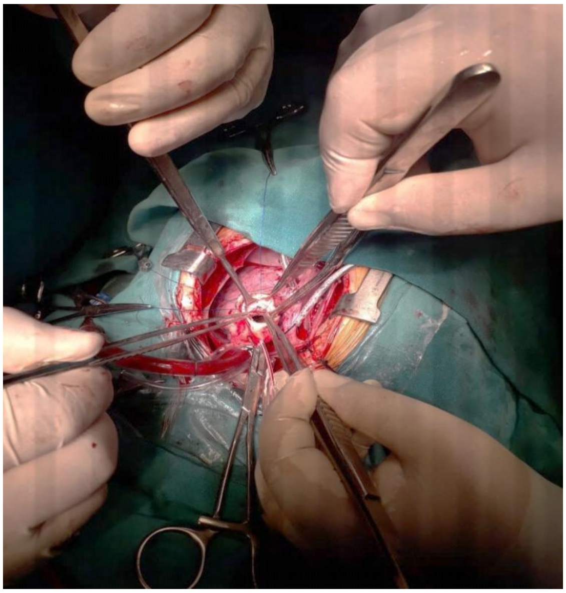

Figure 2. Subaortic VSD closure with fresh autopericardial patch

- In one case the band was tightly adherent and eroding into the wall of pulmonary artery so it was left in its place and the pulmonary artery was incised from above the pulmonary valve to below the bifurcation of pulmonary artery and autopericadial patch was sutured to dilate the site of previous band.
- After closure of VSD a test was done for any residual which was done by positive pressure ventilation and stoping of the vent and watching for any blood coming through any residual defect. Then atriotomy was closed by 5-0 prolene continuos suture.
- De-airing of the left ventricle was done and the aortic cross clamp was removed to allow coronary blood flow to be restored. When heart rhythm was restored and the rate was satisfactory for age; weaning off bypass was gradually achieved after restoration of lung ventilation. If the cardiac output was satisfactory, venous cannulae were removed, and heparinization was reversed using protamine sulfate in a dose of (3-4 mg/Kg IV) and its effect was monitored by ACT and aortic decannulation was continued after reinfusing the remaining amount of patient's blood from the reservoir of the heart-lung machine.
- If the heart failed to restore its normal conductive function; i.e. in cases of postoperative heart block, a temporary cardiac pacemaker was used to pace through the inserted epicardial leads. If the block failed to resolve during the first few days of the ICU stay, a permanent pacemaker was planned in collaboration with pediatric cardiologists. Hemostasis was done properly. 2 ventricular pacing wires were placed in all patients. Retrosternal chest tubes were placed; and pleural chest tubes in cases of opened pleura.
- Sternum was then closed by simple sutures of stainless steel wires passed through the sternum. Followed by closure of the pectoralis fascia using an absorbable suture material (Vicryl). Subcutaneous tissue was closed using

same suture material. And the skin was closed using 3-0 or 4-0 subcuticular suture.

Postoperative parameters

- All patients were transmitted to cardiac ICU while ventilated and on inotropic support. All patients in ICU were fully monitored: invasive blood pressure monitoring, direct CVP measuring, continuous ECG monitoring, urin output hourly monitoring, fluid balance every 8 hours. Chest tubes are monitored considering reopening if the tubes draining more than 3-5 ml/kg/hr fresh blood. Hemodynamic stability is maintained by IV fluid daily from 25% to 50% % of daily requirement, compensation of blood loss as mentored by chest tube drainage compensated by blood and plasma infusion, inotropic support + vasodilator to maintain hemodynamic stability the later are gradually weaned off, and discontinued after gradual weaning from artificial ventilation and extubation is done.
- Criteria of weaning from ventilator: hemodynamic stability, the baby was fully conscious, good muscle power, absence of acidosis or alkalosis, ability of the patient to maintain normal blood gas analysis on CPAP and FIO2 0.3.
- Frequent endotracheal suction is required while the patient was intubated and at extubation. After extubation. The patient was put on O2 mask or nasal prongs from which he is gradually weaned off and maintain good O2 sat and ABG in room air.

Immediate post-operative parameters

These parameters were recorded during the hospital stay, either in ICU or in ward; and include all of the following: (1) Duration of mechanical ventilation (in hours). (2) Duration of ICU stay (in days). (3) Occurrence of any wound infection. (4) Heart rhythm and conduction abnormalities; and the need for temporary or permanent pacemaker. (5) Two dimensional echocardiography is performed for all patients before hospital discharge to assess the following: Presence of residual VSD and its size, and cardiac functions. (6) Hospital stay. (7) Mortality.

Post-operative parameters within 3m after surgery

Presence of residual and its size, presence of LV dilatation and its degree, presence of pulmonary hypertension and its degree, degree of TR, presence AR, cardiac functions, EF and FS, and history and signs of endocarditis.

Post-operative parameters within 6m after surgery

Presence of residual and its size, presence of LV dilatation and its degree, presence of pulmonary hypertension and its degree, degree of TR, presence AR and cardiac functions, EF and FS, history and signs of endocarditis.

Statistical analysis

SPSS (Statistical Package for the Social Science; SPSS Inc., Chicago, IL, USA) version 15 for Microsoft Windows was used for all statistical calculations. The descriptive statistics was presented with mean±standard deviation (SD) or median with interquartile (IQR) range for continuous variables and proportion for categorical variables. Student t-test or Mann -Whitney test was used to compare continuous variables. Data were statistically described in terms of mean + standard deviation (+ SD), median and range, or frequencies (number of cases) and percentages when appropriate. Comparison of numerical variables between the study groups was done using student t test for independent samples in normally distributed data and Mann Whitney U test for independent samples in non-normal data. For comparing categorical data, Chi square (X^2) test was performed. Exact test was used instead when expected frequency is less than 5. P-values less than 0.05 was considered statistically significant.

Results

This study included 60 patients with VSD who underwent surgical VSD closure at Cairo university affiliated hospitals in the period between March 2017 – December 2019. They were divided into 2 groups according to the type of patch used. Group I (30 patients) in whom synthetic (Gortex or dacron) patch was used for surgical closure of VSD, and Group II (30 patients)in whom pericardial patch (fresh or treated or bovine) was used for surgical closure of VSD.

Preoperative results

Mean age in group I was 35.20 ± 28.85 and 30.83 ± 21.60 in group II with no statistical significant differences. Group I included 17 (56.7%) males and 13 (43.3%) females and group II included 14 (46.7%) males and 16 (53.3%) females with no statistical significant difference (Tables 1 & 2). Demographic data of the studied group are illustrated in table 1,2.

Table 1
Demographic data of the studied group

	Number	Percent
Age at op. (m)	33.02 ± 25.36	
Gender		
Male	31	51.7
Female	29	48.3

Data are expressed as mean ± SD or number (%).

Table 2
Comparison between demographic data in the 2 studied groups

	Group I (n= 30)	Group II (n= 30)	p value
Age at op. (yrs.)	35.20 ± 28.85	30.83 ± 21.60	0.510
Gender			
Male	17 (56.7%)	14 (46.7%)	0.438
Female	13 (43.3%)	16 (53.3%)	

As regard preoperative echocardiographic data of the patients, perimembranous VSD was the most common type in both groups 19 (63.3%) patients and 13 (43.3%) patients in group I and II respectively with no statistically significant difference Most of the patients had large VSD >5mm in both groups, 15 (50.0%) patients and 16 (53.3%) patients in group I and II respectively, with no significant difference .findings are shown in table 2. Severe LV dilatation was present in 6(20%) patients and 12(40%) patients in group I and II respectively with no significant difference. Regarding pulmonary hypertension severe pulmonary hypertension was detected in 11(36.7%) patients and 7(23.3%) patients in group I and II respectively with no significant difference. Aortic cusp prolapse was diagnosed in 8(26.7%) patients and 12(40%) patients in group I and II respectively with statistical insignificance. Aortic regurge was diagnosed in 7(23.3%) patients and 8(26.7%) patients in group I and II respectively with no significant difference. Comparison between the two groups regarding echocardiographic data revealed no statistical significant difference .EF and FS were statistically significant higher in group II. These results are shown in (Tables 3& 4). Pulmonary artery banding was present in 5(16.7%) patients in group I and 2(6.7%) patients in group II.

Table 3
Preoperative Echocardiographic findings of the studied group

	Number	Percent
VSD type		
Sub.aortic	20	33.3
Perimemb.	32	53.3
Inlet	4	6.7
Muscular	4	6.7
VSD size		
Small 3-4mm	3	5.0
Moderate 4-5mm	26	43.3
Large>5mm	31	51.7
TR		
Mild	40	66.7
Moderate	16	26.7
Severe	4	6.7
Associated		
No	55	85.9
PDA	9	14.8
ASD	13	21.7
Mild PS	3	5.0
LVD		
Mild	13	21.7
Moderate	29	48.3
Severe	18	30.0
PH		
No	5	8.3
Mild	10	16.7

Moderate	27	45.0
Severe	18	30.0
FS	40.03 ± 4.63	
EF	71.20 ± 6.08	
Aortic prolapse	20	33.3
Aortic regurge	15	25.0

Data are expressed as mean ± SD or number (%)

Table 4
Comparison between preoperative echocardiographic data of the studied groups

	Group I(n= 30)	Group II (n= 30)	p value
VSD type			
Sub.aortic	9 (30.0%)	11 (36.7%)	
Perimemb.	19 (63.3%)	13 (43.3%)	0.344
Inlet	1 (3.3%)	3 (10.0%)	
Muscular	1 (3.3%)	3 (10.0%)	
VSD size			
Small	2 (6.7%)	1 (3.3%)	0.833
Moderate	13 (43.3%)	13 (43.3%)	
Large	15 (50.0%)	16 (53.3%)	
TR			
No	24 (80.0%)	16 (53.3%)	0.061
Moderate	4 (13.3%)	12 (40.0%)	
Severe	2 (6.7%)	2 (6.7%)	
Associated			
No	25 (83.3%)	26 (86.7%)	0.192
PDA	3 (10.0%)	4 (13.3%)	0.688
ASD	5 (16.7%)	8 (26.7%)	0.347
Mild PS	1 (3.3%)	2 (6.7%)	0.554
LVD			
Mild	10 (33.3%)	3 (10.0%)	0.055
Moderate	14 (46.7%)	15 (50.0%)	
Severe	6 (20.0%)	12 (40.0%)	
PH			
No	2 (6.7%)	3 (10.0%)	0.212
Mild	7 (23.3%)	3 (10.0%)	
Moderate	10 (33.3%)	17 (56.7%)	
Severe	11 (36.7%)	7 (23.3%)	
FS	38.33 ± 4.90	41.73 ± 3.69	0004*
EF	69.50 ± 6.56	72.90 ± 5.10	0.029*
Aortic prolapse	8 (26.7%)	12 (40.0%)	0.273
Aortic regurge	7 (23.3%)	8 (26.7%)	0.766

Operative results

Most of patients, 43 (71.7%), patients were approached through the transatrial approach, the rest of patients, 28 patient (28.3%), were approached trough trasaortic approach.(Table 5). In group I transaortic approach was used in 6 patients (20%) and transatrial approach was used in 24 (80%) patients .In group II transaortic approach was used in 11(37%) patients and transatrial approach was used in 19 (63%) patients.

Table 5
Operative results in the studied group

	Number	Percent
TransAortic Approach	17	28.3
TransAtrial approach	43	71.7
Group		
Group I	30	50.0
Group II	30	50.0

Data are expressed as number (%)

In group I synthetic patch Gortex and dactron were equally used (in 15(50%) patients each) while in group II fresh pericardium was used in 25(83%) patients and bovine pericardium was used in only 4(13%) patients and treated autopericardium in 1(3%) patients.(Table 6).

Table 6
Type of patch used in the studied group

	Number	Percent
Group		
Group I Synthetic	*(n=30)*	50.0
Synthetic Gortex	15/30	50.0
Synthetic dacron	15/30	50.0
Group II Pericardial	*(n=30)*	50.0
Fresh pericardium	25/30	83.3
Bovine pericardium	4/30	16.7
Treated autopericardium	1	

Data are expressed as number (%).

Surgical technique of suturing

Continuous sutures were used in 30(100%) patients in group I and 30(100%) patients in group II. Intraoperatively all patients in both groups 60 (100%) had sinus rhythm. Inotropic support was needed in all patients in both groups (100%). In group I ischemic time was 41.83 ± 7.25m versus 32.87 ± 5.05m in group II with Statistical significant shorter time in group II. Regarding pump time it was 58.83 ± 9.44m and 43.00 ± 8.98 in group I and II respectively with significant statistical shorter time in group II. Total operative time was 176±9.65m and 129.6±9.81in group I and II respectively with statistically significant shorter time in group II (Table, 7).

Table 7
Operative results of the studied two groups

	Group I (n= 30)	Group II (n= 30)	p value
Ischemic time(min.)	41.83 ± 7.25	32.87 ± 5.05	0.001*
Pump time (min.)	58.83 ± 9.44	43.00 ± 8.98	0.001*
Total operative time (min)	176±18.65m	129.6±19.81	0.001*

Post-Operative results
ICU results

Ventilation time, was statistically significant shorter in group II (8.53 ± 6.37h) compared with Group I (30.60 ± 20.84h) p value 0.001*.Statistically significant shorter ICU time was found in group II (2.53 ± 0.90d) compared with group I (3.70 ± 1.62d) (Table 8).

Table 8
ICU results of the studied groups

	Group I (n= 30)	Group II (n= 30)	p value
Ventilation time(h)	30.60 ± 20.8	8.53 ± 6.37	0.001*
ICU time(days)	3.70 ± 1.62d	2.53 ± 0.90	0.001*

Regarding cardiac rhythm, 20(66.7%) patients and 28(93.3%) patients in group I and II respectively had sinus rhythm. While 10(33.3%) patients and 2(6.7%) patients in group I and II respectively had compete heart block that necessitate temporary pacing Pacemaker was put intraoperative with statistically significant higher number in group I. Patients with temporary pacing returned to sinus rhythm before ICU discharge, non of them needed permanent pacing (Table 9).

Table 9
Comparison between the incidence of heart block in the 2 studied groups

	Synthetic (n= 30) Group I	Pericardial (n= 30) Group II	p value
HB temporary	10 (33.3%)	2 (6.7%)	0.021*
Sinus Rhythm	20 (66.7%)	28 (93.3%)	0.021*

Regarding postoperative echocardiographic results, residual VSD was found in 8(26.7%) patients in group I and no patient in group II showed residual VSD with statistical significant difference. Residual VSD size was small, 1-2mm, in 6 (20%) patients and moderate 3mm in size in 2(6.7%) patients, causing no hemodynamic instability. These patients were discharged on medical TTT as diuretics and capoten with prophylaxis against endocarditis to be followed after 3 months (Table 10).

Table 10
Comparison between Echocardiographic data in immediate post-operative (ICU)

		Group I	Group II	p-value
Residual VSD (n=8; 26.7%)	Small 1-2mm	6(20%)	0 (0.0%)	0.010*
	Moderate 3mm	2 (6.7%)	0 (0.0%)	
Endocarditis		1(3.3%)	0(0%)	0.313

Postoperative complications (hospital stay)

Four patients (13.3) in group I and 3 (10%) patients in group II had postoperative chest infection with no statistical significant difference. Chest infection was managed by sputum culture and antibiotics were given accordingly. One patient (3%) in group I had wound infection which is treated with repeated dressings, culture and sensitivity and antibiotics accordingly.

Table 11
Comparison between post operative complications in both groups

	Group I (n= 30)		Group II (n= 30)		p-value
	No.	%	No.	%	
Chest infection	4	13.3%	3	10%	0.06
Wound infection	1	3.4%	0	0%	0.49

There was one patient with infective endocarditis in group I presented by persistent fever for 2 days, echocardiography revealed small vegetation on right ventricular side of the patch and blood culture withdrawn revealing *Staph. aureus*, he had leukocytosis and positive CRP. This patient received IV antibiotics according to culture including vancomycin and meronam for 4-weeks. He was discharged after completion of antibiotic course and disappearance of vegetation with normal leucocytic count and CRP. Regarding hospital stay it was 6.8 ± 4.5 in group I and 5.9± 1.14 in group II with statistical significant higher hospital stay in group I (Table 12).

Table 12
Comparison between two groups regarding hospital stay

	Group I (n= 30)	Group II (n= 30)	p-value
Hospital stay duration (days)	6.8 ± 4.5(%)	5.9± 1.14(%)	0.002

All patients were discharged from the hospital on medical treatment of diuretics and after-load reduction (capoten) according to age and weight and there was no mortality in our study.

Three-months follow-up results

All patients completed the three-month follow-up in both groups with no mortality. In follow-up echocardiography after 3-month after operation, six patients (20%) in group I had residual tiny to small defects (1-2 mm) and only two patients had moderate residual (2-4 mm). In group II no residual VSD was detected with statistical significance upon comparison between the two groups. No statistical significant difference was found between the 2 groups regarding LV dilatation, pulmonary hypertension, presence of TR and presence of AR in follow-up. EF was normal in both groups but statistically higher in group II (Table 13). Regarding the patient with infective endocarditis at three-month follow-up, he has no fever, hemodynamically stable with negative blood culture with no vegetation seen in echocardiography.

Table 13
Comparison between the 3-month follow-up results in the 2 groups

		Group I (n=30)	Group II (n=30)	p-value
Residual VSD	No	22 (73.3%)	30 (100.0%)	0.010*
	Small (1-2 mm)	6 (20.0%)	0 (0.0%)	
	Moderate (3-4mm)	2 (6.7%)	0 (0.0%)	
Endocarditis		0 (0.0%)	0 (0.0%)	---
LV dilatation	No	4 (13.3%)	4 (13.3%)	0.540
	Mild	18 (60.0%)	15 (50.0%)	
	Moderate	7 (23.3%)	11 (36.7%)	
	Severe	1 (3.3%)	0 (0.0%)	
EF		64.73 ± 8.37	70.57 ± 5.90	0.003*
FS		39.20 ± 10.18	39.54 ± 4.06	0.871
P. hypertension	No	6 (20.0%)	10 (33.3%)	0.505
	Mild	17 (56.7%)	14 (46.7%)	
	Moderate	7 (23.3%)	6 (20.0%)	
TR (mild)		4 (13.3%)	3 (10.0%)	0.688
AR		9 (30.0%)	7 (23.3%)	0.559

Data are expressed mean ± SD or number (%). p> 0.05= not significant

Six-months follow-up results

All patients completed the 6-month follow-up in both groups with no mortality. Follow-up echocardiography 6-month after operation revealed spontaneous closure of residual VSD in six out of the eight patients in group I. Five patients had small residual VSD and one moderate residual. The remaining two patients had small residual less than 2mm with no hemodynamic effect for follow-up. No residual VSD was found in group II with no significant difference between the 2 groups. No statistical significant difference was found between the 2 groups regarding LV dilatation, pulmonary hypertension, presence of TR and presence of AR (Table 14). No statistical significant difference between 2 groups regarding FS and EF. Regarding the patient with infective endocarditis at six-month follow-up, he has no fever, hemodynamically stable with no vegetation seen in echocardiography.

Table 14
Comparison between the 6 month follow up results in the 2 groups

		Group I (n=30)	Group II (n=30)	p-value
Residual VSD	No	28 (93.4%)	30 (100.0%)	0.206
	Small (1-2 mm)	1 (3.3%)	0 (0.0%)	
	Moderate (3-4mm)	1 (3.3%)	0 (0.0%)	
Endocarditis		0 (0.0%)	0 (0.0%)	---
LV dilatation	No	14 (46.7%)	13 (43.3%)	0.312
	Mild	14 (46.7%)	17 (56.7%)	
	Moderate	2 (6.7%)	0 (0.0%)	
EF		65.50 ± 11.50	68.00 ± 8.35	0.339
FS		42.17 ± 11.60	40.83 ± 7.67	0.601
P. hypertension (mild)		13 (43.3%)	10 (33.3%)	0.426
TR (mild)		2 (6.7%)	0 (0.0%)	0.492
AR		7 (23.3%)	4 (13.3%)	0.506

Data are expressed as mean ± SD or number (%)
$p > 0.05$= not significant; *$p \leq 0.05$= significant

Discussion

Repair of a ventricular septal defect (VSD) is the most frequent paediatric cardiac procedure. A relatively low rate of postoperative complications has been reported in recent studies [8]. To stop the progression of VSD before the onset of severe pulmonary vascular obstructive disease, early primary repair is advised [9]. Surgical repair decrease the risk for endocarditis, PAH may be improved, and overall survival is increased. The surgical mortality rate without PAH is about 1%. Arrhythmias, LV dilatation with or without dysfunction, progression of PAH, tricuspid or aortic valves incompetence are possible complications. Atrial fibrillation, complete heart block, and ventricular tachycardia are some of the arrhythmias that might occur after VSD correction. The presence of irreversible PAH is the principal contraindication for surgical VSD closure.

Indications for surgery include congestive heart failure, failure to thrive, moderate to large defects, unlikely to close spontaneously (with or without symptoms), the development (or progression) of aortic valve leaflet prolapse, and/or aortic insufficiency, as well as asymptomatic (older) children with a Qp:Qs ratio higher than 2.0 [10]. According to the surgeon's preference, synthetic materials such as Dacron (polyethylene terephthalate) or Goretex (expanded polytetrafluoroethylene) are typically used to repair VSDs. In the early postoperative period, echocardiograms frequently detect small residual VSDs that can be sealed off with Dacron by triggering a fibrous reaction. For VSD closure, both autologous and xenograft (bovine, equine) pericardium may be employed. Fresh pericardium that hasn't been treated is tough to handle and over time has the potential to shrink and stretch [7].

A total of 60 patients were recruited for the study. Of these, group I 30 had VSD repair using Gore-Tex or dacron patch and 30 had VSD repair using autologous pericardial patch. In our study group 51.7.33% of the patients were males and 47.3% of them were females. This goes with Topal et al. [11] who reported 59% males and 41% females. In contradictory Amin et al. [12] reported that in their study group 33.33% of the patients were males and 66.67% of them were females. In the current study age range of patient was 4-55 months. Amin et al. [12] reported an almost identical age range of 3–12 m, but their research was intended to assess the effects of preoperative weight less than 5 kg on mortality and morbidity in patients with ventricular septal defects receiving surgical closure. On the other hand, earlier age of surgery was reported by Varghese et al.[13] in their study that included 136 patients with VSD patch closure for isolated VSD, age range was 1-431m, Again, Scully et al. [14] in their study group reported age range from 20 days to 18 years.

Regarding body weight of included patients it was 7.2± 3.2 Kg in group I and 7.8± 3.4 Kg in group II with no significant statistical difference. Azab et al. [15] reported a higher body weight range 3 to 53 Kg mean of 12.14 ± 8.46 Kg. Again, Scully et al. [14] reported median weight of 7 Kg (range, 2 to 66 Kg) this could explained by that they included adolescent patients in their study. In general centers at UK and USA operate mostly at a lower body weight unlike in Egypt that mostly operate at a higher body weight (6-7 Kg). In the present study the most common VSD was perimembranous outlet type comprising 86.6% of the study population. Muscular VSD was the least common with only 6.7% of the population. Regarding associated anomalies ASD was present in 21.7%, PDA in 14.8%, mild valvular PS in 5% patients.

This goes in accordance with Amin et al. [12] who stated that regarding the type of VSD, it was perimembranous VSD in 79.17% patients, muscular VSD in 14.58% patients and subpulmonic VSD within 6.25%. Also Aydemir et al. [16] reported in their study group perimembranous VSD in 83.4%, doubly committed juxta-arterial in 7.4%, 4.6%, inlet nine muscular 3.2%, and 1.4% multiple. On the other hand, Josephraj et al. [17] found outlet VSD in 50% and muscular VSD in 8% of their study group. Preoperative echocardiographic data from 48 patients with VSD included in a study by Amin et al. [12] included associated cardiac anomalies: (58.33%) cases had isolated VSD with no associated cardiac anomalies, and (41.67%) cases had associated simple cardiac anomalies, of which (27.08%) cases had associated ASD, 10.42% cases had associated PDA, and 4.17% cases had associated ASD and PDA. According to our study, 12.3% of patients had related PDA, 7.4% had pulmonary valve stenosis, and 21.8% of patients had associated ASD [8].

Most of our patients 67% are approached through transatrial route. In agreement Amin et al. [12] stated that the majority 89% of VSDs (peri-membranous, inlet, and the majority of muscular defects) were closed via a right atrial approach; however, some 10% VSDs were closed via a trans-pulmonary approach. The majority of VSDs may be closed with a right atrial incision (transatrial approach). This strategy has the following benefits: Looking through the right atrium, through the tricuspid valve, and into the right ventricle, the surgeon examines and fixes the VSD. The septal leaflet of the tricuspid valve may need to be detached in order to see abnormalities in the input septum. Through surgical incision in the ascending aorta, conal VSDs with accompanying aortic valve insufficiency may be approached, allowing VSD closure and aortic valve repair (transaortic approach) [18].

Aortic valve prolapse affected 33% of the individuals in the current study. They were accessed via the transaortic route, and the prolapsed right coronary cusp was repaired using a modified Trusler procedure. Only 3% of the patients in Josephraj et al. study's [17] experienced aortic cusp prolapse and aortic regurge. High percentage of transaortic approach in this study is explained by that high percentage aortic regurge in subaortic VSD may be encountered because of the long wait before surgery compared with developed countries. Advantage of transaortic approach include direct visualization and repair of aortic cusps. Another advantage is direct cardioplegia in coronary sinuses [19]. In the present study continuous suture techniques were used in all patients of the study group. According to Amin et al. [12], all VSDs were closed using a running suture technique with a double-armed, half-circle Prolene needle. A patch consisting of either bovine pericardium or gore-tex was used to close the VSD.

In a research involving 60 children, Okwulehie et al. [20] used autologous pericardium that had undergone glutaraldehyde treatment to cure VSDs. The flaw was fixed using a continuous stitching technique and 4/0 or 5/0 prolene suture. According to Josephraj et al. [17], continuous suture was employed in 40% of patients, and the majority of the patients in this technique group had pericardial organs. A role in the simplicity of surgery was the pericardial patch treated with glutaraldehyde, which was more flexible and had superior handling qualities than the Gore-Tex patch. All of the remaining 60% used an interrupted suture technique and belonged to the Gore-Tex group. During the course of the study, they were primarily operated on by a single surgeon, which may have contributed to the group's employment of the same procedure. According to Us et al. [21], they prefer to close VSDs using a continuous suture approach. On occasion, chordal tissue may cover the defect. These chordal tissues can be navigated by weaving in and out with continuous sutures. Some have suggested detaching the base of the tricuspid septal leaflet to enhance the exposure of a challenging VSD.

According to Muthuvijayan and Kumaravel [22], 40% of the study group used the continuous suture approach. The majority of the patients in this group received pericardial patches. For ease of surgery, the glutaraldehyde-treated patch was more flexible and had superior handling qualities than the Gore-Tex patch. The interrupted suture technique was performed on 60% of the remaining patients, the majority of whom belonged to the Gore-Tex group. Both interrupted and continuous suture techniques work well to close a VSD. 7% of cases of residual shunt occurred with interrupted suture techniques, which is statistically insignificant despite the fact that residual shunt is frequently associated with continuous suture technique VSD closure. Because more pledgets are utilised in interrupted suture techniques, which are also statistically insignificant, the incidence of infective endocarditis is marginally higher in interrupted than continuous suture techniques in their institution.

Pericardial patch was more flexible and had better handling properties compared to the Gore-Tex patch was a contributing factor for ease of surgery [17]. In this study statistical significant shorter ischemic time was found in group II (41.83±7.25m versus 32.87±5.05m in group I and II respectively). Regarding CPB it was 58.83 ± 9.44m and 43.00 ± 8.98 in group I and II respectively with significant statistical shorter time in group II. Total operative time was 176±9.65m and 129.6±9.81in group I and II respectively with statistically significant shorter time in group II. This may be due to in group II most of subaortic VSDs were closed by pericardial patch to avoid distortion of aortic cusp by rigid synthetic patch, This type of VSD is usually associated with aortic cusp prolapse so it is approached through transaortic root to be able to perform aortic cusp resuspension, with this approach the VSD border is evident all through so it takes short time to suture the patch to the border without fear of injuring the AV bundle. In accordance Amin et al. [12] found mean aortic cross-clamp time 45.75 ± 6.24 minutes, mean bypass time was 60.19 ± 6.15 minutes and the mean operative time was 142.02 ±13.44 minutes.

Al-Tae et al. [23] reported mean cardiopulmonary and ischemic times were 90±10.17 and 20±7.15 minutes respectively in a study included 60 patients with VSD closure with treated pericardial patch. On the other hand, Varghese et al. [13] reported longer ischemic time (89.46 ± 47.62m) than ours in group I where synthetic patch was used. In this study ventilation time, was statistically significant shorter in group II (8.53±6.37h) compared with Group I (30.60±20.84h). Statistically significant shorter ICU time was found in group II (2.53 ± 0.90d) compared with group I (3.70 ± 1.62d). We explain this findings by that ischemic time, CPB time and total operative time were shorter and residual defects were less frequent in group II. So the myocardial functions are mores preserved in this group so ventilatory support and consequently ICU time were less in this group. Okwulehie et al. [20] in their study using autologous pericardial patch closure of VSD found longer ventilation time 24h and nearly similar mean ICU stay that was 2 days. Azab et al. [15] reported nearly similar results with mean ICU stay 3±1.24 days.

In our study regarding early post-operative arrhythmia 33.3% in group I and 6.7% patients in group II had temporary incomplete HB that necessitates temporary pacing. Amin et al. [12] in their study found a lower incidence of temporary heart block as 10.4% patients had temporary heart block postoperatively while 89.6% patients had sinus rhythm in contradictory Josephraj et al. [17] found 3% patients had nodal rhythm in Gore-Tex patch group that needed temporary pacing. On the other hand. Muthuvijayan and Kumaravel [22] reported 2.6% patients had nodal rhythm in Gore-Tex patch group and temporary pacing was done but recovered after 6 days. Higher incidence of heart block in this study specially in group I could be related longer by pass and ischemic times which predispose more to myocardial edema.

Residual shunt was present in 26.7% patients in group I which were 13% of all patients included in our study; none of them was hemo-dynamically significant. In group II no residual VSD was detected postoperatively. This is because pericardial patches are more flexible than synthetic patches and they are more aligned with the movement of the septum than the synthetic patches. In accordance Muthuvijayan and Kumaravel [22] found residual shunt in 7.8% of patients in Gortex group, but none of them were significant for re-exploration. In the study of Josephraj et al. [17], postoperative echo showed residual shunt in 30% patients. None of them were significant enough to require re-exploration and closure. The residual shunt was significantly more in whom Gore-Tex was used for VSD closure, irrespective of the type of VSD. Vincent Okwulehie et al. [20] in a study included 60 children had their VSDs repaired with glutaraldehyde – treated autologous pericardium Postoperative echocardiogram revealed trivial shunts in 16% patients. No patient required reoperation for residual VSD.

Amin et al. [12] reported in their studied group that postoperative echocardiographic assessment showed 89.58% cases had no residual flow across VSD while 10.42% cases had residual VSD. After a successful VSD closure, endocarditis incidence is too rare to calculate incidence. Though endocarditis is less likely to occur with bioprosthetic materials like bovine pericardium, it should be kept in mind that this complication is potentially lethal [24]. Endocarditis is a modest but real danger associated with synthetic patches [25]. We reported one patient with infective endocarditis in group I in early postoperative period and he was treated successfully with IV antibiotics for 4 weeks. On the other hand, according to Josephraj et al. [17], two patients in the Gore-Tex group were found to have infective endocarditis and were successfully treated with antibiotics for a period of three weeks based on culture results.

Regarding hospital stay in this study it was 6.8 ± 4.5 in group I and 5.9±1.14 in group II with statistical significant higher hospital stay in group I. In Amin et al. [12] study the mean duration of postoperative hospital stay was 6.0 ± 1.3 days which is comparable with our results in group II. While in the study conducted by Bacha et al. [9] it was 5.4±3.6 days. Longer hospital stay in group I is mostly due to including the infective endocarditis patient with long hospital stay 4 weeks for antibiotic therapy. In our study, follow-up echocardiography after three-month after operation, eight patients (26.7%) in group I had residual defects, non of them required reintervention. In group II no residual VSD was detected with statistical significance upon comparison between the 2 groups. Follow up echocardiography 6-month after operation revealed spontaneous closure of residual VSD in six out of the eight patients in group I non of them required reintervention. Dodge-Khatami et al. [26] concluded that postsurgical residual

VSDs less than 2 mm closed spontaneously in the majority within a year. Defects greater than 2 mm are unlikely to close spontaneously. Dodge-Khatami et al. [26] concluded that postsurgical residual VSDs less than 2 mm generally spontaneously healed within a year. Greater than 2 mm defects are unlikely to close on their own. Saitazizov [27] stated that Follow up was for 1-3-6-12-24-36 months (mean 12 months). No patient required reoperation for residual VSD.

Conclusion

Pericardial patch is simple, easily available, sterile, and non-immune reaction. Fresh or glutaraldehyde-treated autologous pericardium are handled better and easier than other materials with lower incidence of post-operative arrhythmias and residual VSD. We also find that the autologous pericardium is more in harmony with septal movements than synthetic prosthetic materials. Moreover, postoperative infective endocarditis incidence is less when using autologous pericardium. In addition to the previously noted advantages, limited financial resources makes the use of autologous pericardium a good alternative material to be used for repair of VSD.

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References

1. AL-Tae JJ. (2016): Experience with Autologous Pericardial Patch Closure of Ventricular Septal Defect. Iraqi Academic Scientific Journal, 15(1): 58-60.
2. Amato JJ, Douglas WI, AbooEid GJ, Lukash F. (2000): Removal of an infected ventricular septal defect patch after tetralogy repair. Ann Thorac Surg., 70: 2140-42.
3. Amin S, Shawky HA, Abd Allah Rezk TS, Essam A. (2019): Early outcome of ventricular septal defect closure in infants under five kilograms of bodyweight. Journal of American Science, 15(1): 1-7.
4. Aydemir NA, Harmandar B, Karaci AR, Sasmazel A, Bolukcu A, Saritas T, Yucel IK, Coskun FI, Bilal MS, Yekeler I. (2013): Results for surgical closure of isolated ventricular septal defects in patients under one year of age. Journal of Cardiac Surgery: Including Mechanical and Biological Support for the Heart and Lungs, 28(2): 174-9.
5. Azab S, El Shahawy H, Samy A, Mahdy W. (2013): Permanent complete heart block following surgical closure of isolated ventricular septal defect. Egyptian Journal of Chest Diseases and Tuberculosis, 62(3):529-533.
6. Bacha EA, Cao QL, Starr JP, et al. (2003): Perventricular device closureof muscular ventricular septal defect. Thorac Cardia vase Surg., 126:17-18.
7. Dakkak W, Olive T. (2021): Ventricular Septal Defect. Treasure Island (FL): StatPearls Publishing. https://www.ncbi.nlm.nih.gov/books/NBK470330/
8. Dodge-Khatami A, Knirsch W, Tomaske M, Prêtre R, Bettex D, Rousson V, Bauersfeld U. (2007): Spontaneous closure of small residual ventricular septal defects after surgical repair. The Annals of Thoracic Surgery, 83(3): 902-5.

9. Ghosh S, Sridhar A, Solomon N, Sivaprakasham M. (2018): Transcatheter closure of ventricular septal defect in aortic valve prolapse and aortic regurgitation. Indian Heart J., 70(4):528-532.
10. Holzer R, de Giovanni Walsh KP, Tometzki A, Goh T, Hakim F, Zabal C, de Lezo JS, Cao QL, Hijazi ZM. (2006): Transcatheter c losure of perimembranousventricular septal defects using the Amplatzer membranous VSD occluder: Immediate and midterm results of an internationalregistry. Catheter Cardiovasc Interv., 68:620-28.
11. Josephraj G, Anand V, Siddharth VT, Karthikeyan B, Manivannan P, Anandan H. (2017): Comparison of the Outcome of Ventricular Septal Defect Closure using Gore-Tex and Glutaraldehyde-treated Autologous Pericardium. Int J Sci Stud., 5(3):115-118.
12. Mancini MC, Bove EL, Devaney EJ, Ohye RG, Willis PW. (2014): Ventricular Septal Defect Surgery in the Pediatric Patient. E-Medicine. http: //emedicine.medscape.com/article/903271-overview -a1(accessed 30th Nov 2014)
13. Muthialu N, Balakrishnan S, Sundar R. (2018): Single patch closure of multiple VSDs through right atrial approach. Indian Heart J., 70(4):578-579.
14. Muthuvijayan T, Kumaravel A. (2016): Comparative study between interrupted and continuous suture techniques in ventricular septal defect patch closure: A Retrospective analysis. International Journal of Scientific Stud, 4(7): 65-70.
15. Okwulehie V, Ramdoss N, Dharmapuram A, Swain S, Sundararaghavan S, Kona S. (2006): Experience with autologous pericardial patch closure of ventricular septal defect. IJTCVS, 22: 212–214.
16. Pontailler M, Gaudin R, de Bellaing AM, Raisky O. (2019): Surgical repair of concomitant ventricular septal defect and aortic cusp prolapse or aortic regurgitation, also known as the Laubry-Pezzi syndrome. Annals of Cardiothoracic Surgery, 8(3): 438.
17. Roger H. (1879): Clinical researches on the congenital communication of the two sides of the heart by failure of occlusion of the interventricular septum. Bull de l' Acad de Med., 8:1074.
18. Rolo V, Walker I, Wilson K (2015): Ventricular Septal Defects. Paediatric Anaesthesia., Pp. 1-7. https://resources.wfsahq.org/wp-content/uploads/316_english.pdf
19. Saitazizov KB. (2016): The Results of Closure of the Ventricular Septal Defects with Pulmonary Hypertension by Autologous Pericardium. Eastern European Scientific Journal, 5(6): 1-4.
20. *Schipper* M, *Slieker MG*, *Schoof PH*, *Breur J.* (2017): Surgical Repair of Ventricular Septal Defect; Contemporary Results and Risk Factors for a Complicated Course. 38(2):264-270.
21. Schoof PH, Hazekamp MG, van Ulzen K, Bartelings MM, Bruyn JA, Helbing W. (1998): Autologous pericardium for ventricular septaldefect closure. J Heart Valve Dis., 7: 407-409.
22. Scully BB, Morales DL, Zafar F, McKenzie ED, Fraser CD, Heinle JS. (2010): Current expectations for surgical repair of isolated ventricular septal defects. The Annals of Thoracic Surgery, 89(2): 544-51.
23. Topal AE, Eren MN. (2012): Risk factors for the development of pneumonia post cardiac surgery, Cardiovasc J Afr., 23(4): 212–215.

24. *Us MH, Sungun M, Sanioglu S, Pocan S, Cebeci BS, Ogus T, Ucak A, Guler A.* (2004): A retrospective comparison of bovine pericardium and polytetrafluoroethylene patch for closure of ventricular septal defects. *J Int Med Res.*, 32(2):218-21.
25. Varghese R, Saheed S, Ravi AK, Sherrif EA, Agarwal R, Kothandam S. (2016): The "excluding" suture technique for surgical closure of ventricular septal defects: A retrospective study comparing the standard technique. Ann Pediatr Cardiol., 9(3): 229–235.
26. Walther T, Tsang VT, Deanfield JE, de Leval MR. (2003): Closure of recurrent VSD due to dehiscence of calcified patch. Eur J Cardiothorac Surg., 23:246 – 247.
27. Wood P. (1958): The Eisenmenger syndrome or pulmonary hypertension with reversed central shunt. Br Med J., 2(5099):755-62.