Early Outcomes of Glenn Shunt in Patients Aged 3 to 6 Months vs. above 6 Months

Ihab Mohamed Salah El Din Elsharkawy*, Ahmed Mohamed Abd Elmegeed El-Feky, Hossam Mahmoud Hassanein, Tamer Farouk Siam, Mahmoud Saber Elsayed Singer
Lecturer of Cardiothoracic Surgery, Faculty of Medicine, Cairo University, Egypt
***Corresponding author:** Ihab Mohamed Salah El Din Elsharkawy, **Mobile:** (+20) 01222222213,
E-Mail: bebosharkawy@gmail.com

ABSTRACT
Background: Bi-directional Glenn shunt is a well-established procedure performed as a part of the single ventricle palliation pathway. The Bi-directional connection may also provide definitive palliation in certain patients. A major advantage of the cavopulmonary connection is that it diminishes the extent of the inevitable pulmonary recirculation, thereby resulting in a decrease in the workload of the functionally single ventricle.
Objective: To compare the short-term outcome of Glenn operation in patients aged between 3 to 6 months and patients aged 6 months above. **Patients and methods:** Our study was a retrospective randomized trial, carried out in Cairo University Hospitals, in the period between October 2018 and May 2020. Study Population had been randomized into two groups. Group I: 20 patients who underwent Bi-directional Glenn aged 3 to 6 months & Group II: 20 patients who underwent Bi-directional Glenn aged more than 6 months.
Results: There were significant differences between both groups regarding preoperative evaluation including age, weight, sizes of RPA & LPA and McGoon index. Unbalanced AV canal and DILV are most common diagnoses after tricuspid atresia as explained by their natural incidence in single ventricle diseases. There was significant increase in the O_2 saturation in each group. There was insignificant difference between both groups regarding post-operative mortality and morbidity that met with many other similar studies.
Conclusion: This approach had a number of advantages where it eliminates the need for the traditional first-stage procedures, such as systemic arterial shunting and PA banding, which minimizes PA manipulation and subsequent distortion. The reduction in the number of procedures will also have a favorable impact on cost.
Keywords: Bi-directional Glenn shunt, Outcomes, patients aged 3 to 6 months vs. above 6 months.

INTRODUCTION

Bi-directional Glenn (BDG) shunt is a well-established procedure performed as a part of the single ventricle palliation pathway. The Bi-directional connection may also provide definitive palliation in certain patients. A major advantage of the cavopulmonary connection is that it diminishes the extent of the inevitable pulmonary recirculation, thereby resulting in a decrease in the workload of the functionally single ventricle. Other advantages include the avoidance of pulmonary vascular disease, and also major pulmonary arterial distortion [(1)]. Univentricular atrioventricular connection affects approximately 3 % of infants born with congenital heart disease. Early palliative procedure for such infants is mandatory with the goal to relief cyanosis, prevent damage to ventricular functions and pulmonary vasculature, and facilitate future definitive repair by preserving physiologic parameters. The cavopulmonary shunt (superior vena cava to the right pulmonary artery) provides partial physiological correction for those infants. Its main advantage is to provide obligatory pulmonary blood flow, and avoid left ventricular volume overload accompanying systemic-to-pulmonary artery shunt [(2)].

There have been numerous studies looking at the timing of the BDG procedure, with many highlighting the potential benefits of performing an ‘‘early’’ BDG procedure. These include removing a volume load from the single ventricle that can benefit atrioventricular (AV) valve insufficiency and perhaps improve long-term diastolic function, decreasing the effective cardiac output required from the single ventricle, avoiding potential pulmonary tree distortions seen with systemic to pulmonary shunts, and perhaps preventing the development of pulmonary vascular obstructive disease [(3)]. Despite increased reports in the literature documenting the early BDG procedure, there is continued controversy regarding the timing, with some arguing little benefit in waiting beyond 6 months [(4, 5)]. On the other hand, others are cautioning against performing the procedure in those younger than 6 months. These cautions stem from concern with possibly increased mortality and morbidity with an early Glenn procedure; the possibility that the pulmonary arteries will not be as well developed with passive flow, and the potential adverse effects on cerebral circulation or long-term candidacy for Fontan completion. The ideal age and age limits to perform the Glenn procedure remain uncertain [(6)]. The aim of the study was to compare the short-term outcome of Glenn operation in patients aged between 3 to 6 months and patients aged 6 months and above, to show whether it is safe to perform Glenn operation before 6 months of age or not.

PATIENTS AND METHODS

This was analytical observational retrospective study, 40 patients indicated for Glenn shunt were included after institutional and local ethical committee approval. The study was done at Cairo University

Received: 16/06/2022
Accepted: 24/08/2022

Hospitals (Abu El Reesh specialized pediatric Japanese hospital), in the period between October 2018 and May 2020. All patients went through preoperative, operative & early postoperative evaluation.

Study Population randomized in two groups: *Group I*: 20 patients who underwent Bi-directional Glenn aged 3 to 6 months, and ***Group II*:** 20 patients who underwent Bi-directional Glenn aged more than 6 months.

Inclusion criteria: Patients not suitable for primary Fontan repair and do not need arterial shunt: (1) All patients with functional univentricular hearts including: (a) Tricuspid atresia. (b) Unbalanced AV canal. (c) Double inlet left ventricle. (d) Single ventricle. (2) Arterial oxygen saturation below 75 %. (3) McGoon ratio more than 1.5. (4) No previous palliative procedure. (4) No intracardiac or other procedures were done in the setting of the Bi-directional cavopulmonary procedure, e.g., septectomy or valve repair.

Exclusion criteria: (1) Patients who are amenable to biventricular repair. (2) Associated anomalies. (3) Other operations with Glenn. (4) Redo cases.

All patients were studied for the following variables:

A: Preoperative Variables

I) Thorough history:

A thorough and detailed history was taken, as regards the age, gender, body weight, symptoms: central cyanosis, cyanotic spells, ease at feeding, poor weight gain, repeated chest infections and congestive heart failure.

II) Clinical evaluation: Including general and local examination for all patients:

a) General examination: (1) The weights of the patients were recorded to detect stunted growth. (2) Cyanosis and clubbing. (3) Signs of congestive heart failure including congested neck veins, hepatomegaly and lower limb edema. (4) Chest examination to exclude chest infection.

b) Local examination: (1) Inspection and palpation for active pericardium, and any thrills. (2) Auscultation for murmurs to detect any atrioventricular regurge, ventricular septal defect, and pulmonary stenosis.

III) Laboratory investigations:

Complete blood count (CBC), Liver function tests, prothrombin time and concentration, kidney function tests and serum electrolytes.

IV) Chest X-ray:

It was made for every patient in postero-anterior view to reveal: (1) Cardiac silhouette. (2) Pulmonary artery size. (3) Pulmonary vasculature.

V) Echo - Doppler study

Echo has been an important tool in the diagnosis and assessment of patients with univentricular hearts.

Morphologic and functional evaluation: Using both M-mode and two-dimension echocardiography the following are assessed:

a. Chamber morphology.
b. Relation of the great vessels.
c. Persistent left superior vena cava.
d. Evaluation of the main pulmonary artery and its two branches as concerning size, McGoon ratio, and estimated pulmonary artery pressure using transpulmonary gradient.
e. Exclusion of any anomalous pulmonary venous drainage.
f. Ventricular function using fractional shortening, and ejection fraction ratios.

VI) MSCT:

Three-dimensional imaging is particularly useful in the diagnosis of complex congenital heart disease with accurate measurement of the pulmonary artery and its branches sizes and also the McGoon index. Which, is determined by echo or MSCT.

B: Intraoperative Variables:

***I)* Anesthetic technique:**

The intraoperative anesthetic technique was the same for all patients and consisted of fentanyl 2-3 ug/kg and endotracheal intubation was facilitated with the use of pancuronium 0.08 mg/kg. Additional dose of fentanyl 2-3 ug/kg. was given on need bases. After full muscle relaxation, the trachea was intubated orally with an appropriately sized single lumen endotracheal tube. Anesthesia in all patients was maintained with inhalation 1% isoflurane.

II) Surgical procedure:

All patients were submitted to Glenn shunt through median sternotomy incision. The patient was placed in a supine position with the arms placed by his/her side. A sandbag is put under the shoulders. The patient was then draped in the usual fashion with exposure of the sternum up to the mid clavicular line, and at least one groin. The sternal notch and the tip of the xiphoid process were identified by palpation, and the incision was begun and was extended with electrocautery down to the sternal periosteum. The linea alba was divided at the xiphoid. The sternum was then divided by electric saw. A sternal retractor with broad blades was placed and opened slowly. The sternum was opened as wide as it was necessary to obtain adequate exposure. The pericardium was opened after dissecting the thymus gland, and identifying the left innominate vein. Stay sutures by heavy silk and suturing the pericardium to the edges of the incision usually gave adequate exposure. The superior vena cava is dissected from the pericardial covering till the atrio–caval junction. Dissection is also extended to separate the superior vena cava from the right pulmonary artery. The lateral aspect of the superior vena cava is dissected with great carefulness to avoid injury of the right phrenic nerve. The azygous vein is identified and ligated.

Off pump patients

The procedure was done on a beating heart without using cardiopulmonary bypass. The shunt was done while applying vascular clamp to SVC. All cases were done using cavo-atrial shunt, where the superior vena cava was bypassed into the right atrium or the inferior vena cava using 2 right angled metal tipped cannulae connected together, after full heparinization was achieved. Proper cannula selection was necessary to avoid higher SVC pressure.

On pump patients

The procedure was done on pump beating heart, after heparinization, routine aortic cannulation was done, high selective SVC cannulation was done using a metal tip right-angled venous cannula thus keeping it away from site of anastomosis. The right atrium was cannulated as usual by appropriate venous cannula according to body surface area. Snare was placed around the superior vena cava cannula.

Anastomosis

After adequate mobilization of SVC, the azygos vein is doubly ligated with fine silk ties, or clipped and divided between the ligatures to allow full mobilization of the superior vena cava and Rt. main pulmonary artery. The superior vena cava is transected after applying vascular clamp about half centimeter above the cavo-atrial junction to avoid injury of sino-atrial node.

The right atrium-superior vena cava junction is oversewn with a running prolene 5-0 suture, and the vascular clamp is removed to prevent twisting of the proximal superior vena cava, after transection the azygos vein may be simply ligated or, occluded with a metal clip. This maintains the correct orientation of the superior vena cava during its anastomosis to the pulmonary artery. Alternatively, marking sutures may be placed on the superior vena cava to maintain the orientation of the vessel during the anastomosis. The superior aspect of the right pulmonary artery is grasped with a curved clamp, and an opening on the superior aspect of the right pulmonary artery is made with a knife blade and Potts scissors.

The anastomosis of the superior vena cava to the right pulmonary artery is then accomplished with a running prolene 6-0 or 7-0 suture beginning at the most medial aspect of the pulmonary arteriotomy, completing the posterior row with one needle and then the anterior aspect with the second needle.

The clamp on the pulmonary artery is removed, and the anastomosis is inspected for bleeding and patency. Routine decannulation, hemostasis and closure of the sternotomy.

C: Post-Operative Variables

All patients were transferred to the intensive care unit nursed in a semi-setting position to encourage shunt flow and managed as follows:

1- Continuous monitoring of: Electrocardiogram (rate and rhythm), arterial blood pressure, central venous pressure, peripheral body temperature and oxygen saturation through a pulse oximetry, and fluid chart and urinary output.

2- Mechanical ventilation: The Pressure-limited ventilators were used at low ventilatory settings. Weaning and extubation followed gradually after complete stabilization of both cardiovascular and respiratory status.

Criteria for weaning and extubating patients with Bi-directional cavopulmonary shunt includes:

Early extubation was planned in all of our patients:

- Adequate level of consciousness.
- Hemodynamics stability with minimal mediastinal bleeding (less than 1 ml/Kg/min) and adequate peripheral perfusion.
- PaO_2 more than 40 mmHg and O_2 saturation of 80% on fraction of inspired oxygen of 40%
- $PaCO_2$ less than 50 mmHg.
- Normothermia.

3- Cardiovascular management:

- Inotropic support as adrenaline might be used if needed.
- Diuretics and vasodilators might be used.

4- Regular checking of:

- Urine output / hour.
- Drains output / hour.
- Arterial blood gases and electrolyte balance
- Blood chemistry for blood sugar, coagulation profile, hepatic and renal functions.

Postoperative outcomes checklist:

1- Hemodynamics: either stable or unstable.
2- Glenn pressure.
3- Postoperative SO_2 at time of discharge from hospital.
4- Echocardiography: to detect a laminar or a sluggish flow.
5- Hospital stay length.
6- Complications: Mortality, effusions, shunt failure, stroke, arrhythmias and bleeding.

Ethical consent:

An approval of the study was obtained from Cairo University Academic and Ethical Committee. Every patient signed an informed written consent for acceptance of participation in the study. This work has been carried out in accordance with The Code of Ethics of the World Medical Association (Declaration of Helsinki) for studies involving humans.

Statistical methods

Data were coded and entered using the statistical package for the Social Sciences (SPSS) version 28 (IBM Corp., Armonk, NY, USA). Data were summarized using mean and standard deviation for quantitative variables and frequencies (number of cases) and relative frequencies (percentages) for categorical variables. Comparisons between groups were done using unpaired t test in normally distributed quantitative variables while non-parametric Mann-

Whitney test was used for non-normally distributed quantitative variables. For comparing categorical data, Chi square (χ^2) test was performed. Exact test was used instead when the expected frequency is less than 5. P- ≤ 0.05 was considered as statistically significant**.**

RESULTS

Table (1) showed significant difference between both groups regarding age and weight, and no significant difference regarding sex.

Table (1): Demographic and pre-operative data

		Group 1		Group 2		
		Mean	**Standard deviation**	**Mean**	**Standard deviation**	**P value**
Age (m)		5.30	0.86	11.55	0.89	< 0.001
Weight (kg)		5.45	1.20	8.02	1.32	< 0.001
		Count		**%**	**Count**	**%**
Sex	**Male**	12		60.0%	11	55.0%
	Female	8		40.0%	9	45.0%

Table (2) showed significant difference between both groups regarding size of RPA, size of LPA and the McGoon index, and no significant difference regarding pre-operative O_2 saturation.

Table (2): Pre-operative data

	Group 1		Group 2		P value
	Mean	**Standard deviation**	**Mean**	**Standard deviation**	
Pre op. Saturation %	63.55	6.72	61.30	5.94	0.269
Size of pulmonary arteries (RPA) mm	6.59	1.69	8.24	1.53	0.003
Size of pulmonary arteries (LPA) mm	5.57	1.34	8.16	1.76	<0.001
McGoon Index	1.76	0.20	2.08	0.36	0.001

RPM: Right pulmonary artery **LPM:** Left pulmonary artery

Table (3) showed no significant difference between both groups regarding pre-operative indication (diagnosis).

Table (3): Pre-operative indication

		Group 1		Group 2		
		Count	**%**	**Count**	**%**	**P value**
Pre-operative indication	**Unbalanced AV canal**	5	25.0%	4	20.0%	0.885
	Tricuspid Atresia	8	40.0%	6	30.0%	
	T.O.F	1	5.0%	2	10.0%	
	DORV	2	10.0%	4	20.0%	
	DILV	3	15.0%	2	10.0%	
	D-TGA	1	5.0%	2	10.0%	

Table (4) showed no significant difference between both groups regarding intra-operative on/off pump.

Table (4): Intra-operative on/off pump

		Group 1		Group 2		P value
		Count	**%**	**Count**	**%**	
On/Off pump	**On**	9	45.0%	5	25.0%	0.185
	Off	11	55.0%	15	75.0%	

Table (5) showed no significant difference between both groups regarding Glenn pressure, post-operative O_2 saturation and hospital stay.

Table (5): Post-operative data

	Group 1		Group 2		
	Mean	**Standard deviation**	**Mean**	**Standard deviation**	**P value**
Glenn pressure	10.75	2.36	10.70	1.84	0.470
Post op. O_2 saturation %	83.70	5.26	81.25	9.06	0.302
Hospital stay (days)	8.40	8.40	7.60	5.75	0.640

Table (6) showed significant difference in group 1 regarding pre-operative and post-operative O_2 saturation.

Table (6): Group 1 pre-op vs. post-op saturation

	Group 1		P value
	Mean	Standard deviation	
Pre-op. O_2 saturation %	63.55	6.72	< 0.001
Post-op. O_2 saturation %	83.70	5.26	

Table (7) showed significant difference in group 2 regarding pre-operative and post-operative saturation.

Table (7): Group 2 pre-op vs. post-op O_2 saturation

	Group 2		P value
	Mean	Standard deviation	
pre op. O_2 saturation %	61.30	5.94	< 0.001
Post op. O_2 saturation %	81.25	9.06	

Table (8) showed no significant difference between both groups regarding post-operative echo.

Table (8): Post-operative echo

		Group 1		Group 2		P value
		Count	%	Count	%	
Echo	**laminar flow across the Glenn**	20	100%	20	100%	1

Table (9) showed no significant difference between both groups regarding complications and mortality.

Table (9): Post-operative morbidity and mortality

		Group 1		Group 2		
		Count	%	Count	%	P value
Complications	**Yes**	2	10.0%	2	10.0%	1
	No	18	90.0%	18	90.0%	
Mortality	**Mortality**	1	5.0%	1	5.0%	1
	Alive	19	95.0%	19	95.0%	

Table (10) showed complications details with no significant difference between both groups.

Table (10): Complications details

		Group 1		Group 2		P value
		Count	%	Count	%	
Complications details	**Arrhythmia**	0	0.0%	1	5.0%	1
	Effusions	1	5.0%	1	5.0%	
	Phrenic nerve injury	1	5.0%	0	0.0%	
	No	18	90.0%	18	90.0%	

DISCUSSION

The results of Bi-directional cavopulmonary anastomosis in older children have been very encouraging with low operative mortality and excellent palliation being achieved in most patients. The logical extension of these results is the application of Bi-directional cavopulmonary anastomosis to younger patients, including infants [(7)].

As regards age, in our study, the mean of the patients in group I was 5.30 ± 0.86 months, ranging from 3 to 6 months and the patients in group II was 11.55 ± 0.89 months, ranging from 9 to 12 months. Our study shows significant difference between both groups (P < 0.001) that is similar to study performed by **Ota *et al.*** [(8)] where they compared outcomes of Glenn between two groups of age < 4 months (younger group) & older than 4 months of age (older group), with significant difference between both groups (P < 0.0001). In addition, another study performed by **Cleuziou *et al.*** [(9)], also showed significant difference between two age groups; group I was 6 months or less of age at the time of Glenn (4.6 ± 1 months), while group II was older than 6 months of age (16.6 ± 17 months) (P < 0.001).

As regard sex, in our study, group I had 12 males (60 %) and 8 females (40 %), while, group II had 11 males (55 %) and 9 females (45 %). Our study showed male predominance. This is in agreement with the natural incidence of male predominance in single ventricle disease. Similarly, **Ota *et al.*** [(8)], also found male predominance in his study, group I had 62.5 % males and group II had 53.9 % males.

As regard sizes of RPA, LPA & McGoon index, in our study, the mean of the patients in group I was 6.59 ± 1.69 mm, 5.57 ± 1.34 mm & 1.76 ± 0.20 respectively, and in group II was 8.24 ± 1.53 mm, 8.16 ± 1.76 mm & 2.08 ± 0.36 respectively, with significant difference between all of the parameters in both groups. Our study showed significant difference between the sizes of RPA, LPA & McGoon index in both groups, this significance is normally expected as regards age and weight of the patients. This is similar to a study performed by **Cleuziou *et al.*** [(9)] that showed significant difference between the sizes of RPA, LPA in the two age groups 7 ± 2 mm in group I and 9 ± 3 in group II (p < 0.001), 6 ± 2 mm in group I and 8.2 ± 3 mm in group II (p < 0.001).

As regards preoperative diagnosis (indication), in our study, spectrum of cases in group I included 8 patients (40.0%) had tricuspid atresia, 5 patients (25.0%) had unbalanced atrioventricular canal, 3 patients (15.0 %) had double inlet left ventricle, 2 patients (10.0%) had double outlet right ventricle, 1 patient (5.0%) had transposition of great arteries, and 1 patient (5.0 %) had tetralogy of Fallot. Spectrum of cases in group II includes 6 patients (30.0%) had tricuspid atresia, 4 patients (20.0%) had double outlet right ventricle, 2 patients (10.0 %) had double inlet left ventricle, 2 patients (10.0%) had transposition of great arteries, and 2 patients (10.0%) had tetralogy of Fallot. Tricuspid atresia is the most common diagnosis in our study, explained by its incidence among univentricular and cyanotic heart diseases. Tricuspid atresia is the third most common cyanotic heart disease after [(10)].

As regards using cardiopulmonary bypass, in our study, off pump was more common in both groups, in group I, there was 11 off pump (55.0%) to 9 on pump (45.0%).

5 patients who were on pump originally intended to undergo non–CPB, but ended up intraoperatively with conversion to CPB, 4 patients because of hemodynamic instability, and 1 patient because of frequent arrhythmias. Also, in group II, 15 off pump (75.0%) to 5 on pump (25.0%), 3 patients who were on pump originally intended to undergo non–CPB, but ended up intraoperatively with conversion to CPB because of hemodynamic instability. In our study, the incidence of on pump is much more in group I (45.0%) than in group II (25.0%). This is due to those patients in group I had small body weight and small size of the pulmonary arteries, making the anastomosis more difficult and more critical, thus using CPB is to ensure safety of the patients. In our study, the incidence of off pump was more common in group I and group II. This is due to that our center preference for performing Glenn off pump with temporary internal shunt to avoid complications that might result from using CPB, which was evaluated in the outcomes of the patients who underwent Glenn on pump. This is in agreement with **Cleuziou *et al.*** [(9)] who reported that 23 patients (27%) were on pump and 61 patients (73%) were off pump in the two age groups (group I was 6 months or less of age at the time of Glenn, while group II was older than 6 months of age).

As regard postoperative Glenn pressure, in our study, the mean of the patients in group I was 10.75 ± 2.36 mmHg and the patients in group II was 10.7 ± 1.84 mmHg with insignificant difference between both groups. The Glenn pressure was within normal range with subsequent laminar flow across Glenn shunt. This is in agreement with **Jaquiss *et al.*** [(5)] showed that the mean Glenn pressure was 14 ± 5 mm Hg in the younger patients, and 15 ± 5 mm Hg in the older group.

As regard pre & post - operative O_2 Saturation, our study showed significant increase in the O_2 saturation in each group, as mean of patients in group I preoperatively was 63.55 ± 6.72% and

postoperatively was 83.70 ± 5.26%. Also, in group II preoperatively was 61.30 ± 5.94%, and postoperatively was 81.25 ± 9.06%. This is in agreement with a study performed by **Cleuziou *et al.*** [9] who reported a significant increase in oxygen saturation from (73 ± 11 %) prior to Glenn to (80 ± 5%) postoperatively in group I, and from 75 ± 8 % to 80 ± 6 % in group II.

As regards length of hospital stay, in our study, the mean of patients in group I was 8.40 ± 8.40 days, and in group II was 7.60 ± 5.75 days. Our study showed insignificant difference between both groups. This is similar to a study performed by **Jaquiss *et al.*** [5] who reported that the median postoperative hospital stay was 12.5 ± 11.5 days in the younger group, and 10.3 ± 14.8 in the older group. Also, **Reddy *et al.*** [4] showed that the median postoperative hospital stay was 7 days.

As regards the outcome and complications, in our study, the mortality in both groups was similar, one patient in each group (5.0%). Mortality in our study, 1 patient (5.0%) had bilateral phrenic nerve paralysis that led to failure of weaning from ventilator ending with death from respiratory failure and sepsis. While in group II, 1 patient (5.0%) died from arrhythmia (Ventricular fibrillation) and cardiac arrest. The hospital mortality rate varied from 0% to 33% in various studies reported by **Manuel *et al.*** [11] where mortality was 16.7 % because of multiple organ dysfunction due to sepsis, shunt occlusion, and cardiogenic shock. Our study showed insignificant difference between mortality rate in both groups, which is similar to a study performed by **Ota *et al.*** [8] who reported 15 hospital deaths following Glenn shunt; 7.5% in the younger group, and 2.9% in older group (P = 0.1). In the younger group, patients who died had respiratory issue due to aspiration, persistent atrioventricular valves regurgitation and sudden hemodynamic instability. While in the older group, patients died from infection, respiratory issue and hypoxia. In another study performed by **Reddy *et al.*** [4] on infants less than 6 months old with mean age of 3.7 ± 1.4 months, there were two early deaths in the study group (4.8%). One early death was due to low cardiac output and poor oxygen saturation ending with cardiac arrest. The other early death was a patient with tricuspid atresia who had persistent low saturation ending with cardiac arrest.

In our study, the morbidity in both groups was similar, two patients in each group (10.0%); two patients had effusive complications, one patient had phrenic nerve injury and the other had arrhythmia. That is similar to a study performed by **Cleuziou *et al.*** [9] who reported in his patient cohort, postoperative study that morbidity was low and no difference between the two age groups. Also, **Reddy *et al.*,** [4] who showed early results in his cohort of young infants had been similar to those in older patients undergoing Glenn during the same period.

Effusions, in group I, 1 patient (5.0%) had chylothorax that needed free fat diet and bilateral chest tubes with prolonged hospital stay (40 days) until the chylothorax had resolved. The incidence of chylothorax was low because of the careful dissection carried out during the surgery. While in group II, 1 patient (5.0%) had bilateral pleural effusion that required bilateral chest tube insertion for 14 days until removal. **Kogon *et al.*** [12] reported incidence of effusions in 22 patients (8.1%), pericardial effusion requiring re-drainage in 2 patients (2.8%), pleural effusion requiring re - drainage in 10 patients (3.7%), and chylothorax requiring no-fat or low-fat diet in 10 patients (3.7%). He reported that complications were due to elevated central venous pressure and elevated transpulmonary gradient.

Concerning phrenic nerve injury, there was 1 patient (5.0 %) in group I only with bilateral phrenic nerve paralysis that led to failure of weaning from ventilator ending with death from respiratory failure and sepsis. In a study performed by **Cleuziou *et al.*** [9]**,** there was a temporary hemi-diaphragm paralysis in four patients, 1 in group I (3.5%) & 3 in group II (5.3%) (p = 0.7).

Regarding arrhythmias, in group II only 1 patient (5.0%) had ventricular fibrillation ending with death by cardiac arrest. This is in agreement with **Cleuziou *et al.*** [9] who reported rhythm disturbances in 3 patients (5.3%) all were in group II (p = 0.5). In addition, **Kogon *et al.*** [12] reported dysrhythmia in 28 patients (10%).

Timing of Glenn shunt

In our study there was no significant difference in the outcomes between both groups, Glenn shunt can be performed on an elective basis in infants 3 - 6 months of age as a primary procedure, with results similar to those achieved in older patients. This shunt in patients 3 - 6 months of age provides early relief from the ventricular volume loading and elevated pulmonary artery pressure of systemic to pulmonary artery shunting, with no increase in morbidity or mortality, and thus is likely to be a preferable strategy for the early palliation of single ventricle heart patients providing confluence and good pulmonary artery branches size. Similar to our study, **Reddy *et al.*** [4] reported that the outcomes of Glenn procedure performed at the University of California at San Francisco in infants < 6 months of age were similar to older infants undergoing Glenn during the same period. Similar to our study, **Cleuziou *et al.*** [9]**,** reported that Glenn procedure can be performed with excellent results even at an age of 6 months or less.

Hemodynamic and clinical data demonstrate that the outcome is equal to that in older patients. For this reason, we will adhere to our current management which is performing an elective Glenn at the age of 3-6 months.

Talwar *et al.* [13], reported that in their experience the outcomes were similar compared to the older population and the only difference was that patients younger than 6 months had a longer intensive care unit stay. We believe that Glenn procedure can provide effective palliation for carefully selected patients, including small infants and young adults.

CONCLUSION

Glenn shunt can be performed on an elective basis in infants 3 - 6 months of age as a primary procedure safely. This approach has a number of advantages where it eliminates the need for the traditional first-stage procedures, such as systemic arterial shunting and PA banding, which minimizes PA manipulation and subsequent distortion. The reduction in the number of procedures will also have a favorable impact on cost. It also decreases the length of time in which the single ventricle is volume overloaded. Excessive shear force on the pulmonary vasculature is also reduced. There were no significant differences between both groups in Glenn procedure concerning postoperative mortality and morbidity.

REFERENCES

1. **Van Praagh R, Ongley P, Swan H (1964):** Anatomic types of single or common ventricle in man: morphologic and geometric aspects of 60 necropsied cases. Am J Cardiol., 13: 367–386.
2. **Glenn W, Ordway N, Talner N *et al.* (1965):** Circulatory bypass of the right side of the heart. VI. Shunt between superior vena cava and right pulmonary artery. Report of clinical application in thirty-eight cases. Circulation, 31: 172-189.
3. **Reddy V, Liddicoat J, Hanley F (1995):** Primary Bi-directional superior cavopulmonary shunt in infants between 1 and 4 months of age. Ann Thorac Surg., 59: 1120-1126.
4. **Reddy V, McElhinney D, Moore P *et al.* (1997):** Outcomes after Bi-directional cavopulmonary shunt in infants less than 6 months old. J Am Coll Cardiol., 29: 1365-1370.
5. **Jaquiss R, Ghanayem N, Hoffman G *et al.* (2004):** Early cavopulmonary anastomosis in very young infants after the Norwood procedure: impact on oxygenation, resource utilization, and mortality. J Thorac Cardiovasc Surg., 127: 982-989.
6. **Ashburn D, Blackstone E, Wells W *et al.* (2004):** Determinants of mortality and type of repair in neonates with pulmonary atresia and intact ventricular septum. J Thorac Cardiovasc Surg., 127: 1000-1008.
7. **Slavik Z, Lamb R, Webber S *et al.* (1996):** Bi-directional superior cavopulmonary anastomosis: how young is too young? Heart, 75: 78-82.
8. **Ota N, Tachibana T, Asai H *et al.* (2020):** Outcomes of Bi-directional cavopulmonary shunt in patients younger than 4 months of age. Eur J Cardiothorac Surg., 57 (5): 937-944.
9. **Cleuziou J, Schreiber C, Cornelsen J *et al.* (2008):** Bi-directional cavopulmonary connection without additional pulmonary blood flow in patients below the age of 6 months. European Journal of Cardio-Thoracic Surgery, 34 (3): 556–562.
10. **Hoffman J, Kaplan S (2002):** The incidence of congenital heart disease. J Am Coll Cardiol., 39: 1890–1900.
11. **Manuel V, Morais H, Turquetto A *et al.* (2019):** Single ventricle palliation in a developing Sub-Saharan African country: What should be improved?. World J Pediatr Congenit Heart Surg., 10: 164-170.
12. **Kogon B, Plattner C, Leong T *et al.* (2008):** The Bi-directional Glenn operation: a risk factor analysis for morbidity and mortality. J Thorac Cardiovasc Surg., 136: 1237-1242.
13. **Talwar S, Sandup T, Gupta S *et al.* (2018):** Factors determining early outcomes after the Bi-directional superior cavopulmonary anastomosis. Indian J Thorac Cardiovasc Surg., 34: 457-467.