

OFF-PUMP BIDIRECTIONAL GLENN SHUNT USING CLAMP & SEW TECHNIQUE

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ABSTRACT

Objective: To evaluate the efficacy of performing Bidirectional Glenns (BDG) using “clamp and sew technique”.

Design: Quasi-experimental study.

Place and Duration of Study: Armed Institute of Cardiology / National Institute of Heart Diseases, Rawalpindi from 1st January 2011 to 31st December 2013.

Methods: All patients subjected to BDG using clamp and sew technique during study period were included. The salient operative steps included. 1) Dissection of superior vena cava, azygous vein and pulmonary arteries 2) Clamping and division of superior vena cava at cardiac end 3) Clamping of ipsilateral branch pulmonary artery and its anastomosis to the divided superior vena cava. Observed variables included oxygen saturations and internal jugular venous pressure before, during and after the procedure, postoperative ventilation requirements, ICU stay, neuro-cognitive assessment, pleural drainage and mortality.

Results: A total of 27 patients were included. 85.2% patients had unilateral BDG while 14.8% patients had bilateral BDG. Mean internal jugular venous pressure on clamping superior vena cava was 29.21 ± 6.13 mmHg (range 19-23 mmHg) and mean clamp time was 14.32 ± 3.39 minutes with a range of 11–21 minutes. Mean Glenn pressure was 14.29 ± 2.53 (range 12–18 mmHg). Mean postoperative Oxygen saturation was $86.07 \pm 2.71\%$ which was significantly increased as compared to preoperative oxygen saturation of $71 \pm 5.16\%$ ($p < 0.001$). Mean ICU stay was 70.45 ± 8.94 hours (38-210 hours). No neuro-cognitive impairment was observed and there was no 30 day in hospital mortality.

Conclusions: Off-pump BDG with clamp and sew technique is a safe procedure in selective patients. It avoids the need for cardiopulmonary bypass and high cost associated with it.

Keywords: Bidirectional Glenn, Clamp and sew, Off-pump, Neurological injury

INTRODUCTION

Armed Forces Institute of Cardiology / National Institute of Heart Diseases (AFIC/NIHD), Rawalpindi has a well-organized program for the management of patients with single ventricle anomaly^{1,2}. These patients require a sequence of palliative procedures culminating in to Fontan circulation over a period of 3-4 years³⁻⁵. Bidirectional Glenn (BDG) is a very important intermediate surgical step in the management of these patents. BDG is characterized by an end to side anastomosis of superior vena cava (SVC) to the ipsilateral pulmonary artery. This procedure can be done with or without cardiopulmonary bypass (CPB) support^{6,7}. However, operation without CPB can

result in significant elevation of the proximal SVC pressure during clamping that may lead to neurological damage⁸. Various techniques like temporary veno-atrial or veno-pulmonary shunts have been used to decompress SVC during clamping^{2,9-12}. We at AFIC/NIHD initially started performing BDG with CPB and later on in 2006 in selected cases shifted to off pump BDG with SVC decompression using veno-atrial bypass². In 2011 we started performing BDG without cardio pulmonary or local bypass by simply clamping the SVC and anastomosing it to pulmonary artery. In this study results of BDG performed using this clamp and sew technique were described.

PATIENTS AND METHODS

This quasi-experimental study was carried out from 1st January 2011 to 31st December 2013 at AFIC/NIHD, Rawalpindi. All patients subjected to Clamp and sew off pump BDG during this

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Received: 05 Feb 2014; Accepted: 05 Mar 2014

period were included in the study. All other

Thorough evaluation with echocardiography

Table-1: Pre-requisites for Bidirectional Glenn.

1. Mean Pulmonary artery pressures of ≤ 18 mmHg
2. Pulmonary vascular resistance of ≤ 2 (and < 4) Wood units but reactive to vasodilators
3. McGoon ratio > 1.8 and repairable
4. \leq mild atrio-ventricular valve(s) regurgitation
5. \leq mild ventricular dysfunction as estimated on echocardiography
6. Left ventricular end diastolic pressure (LVEDP) ≤ 12 mmHg
7. If branch pulmonary artery stenosis is present it should be surgically repairable
8. Normal systemic venous return

Table-2: Characteristics of patients undergoing Clamp and sew BDG (n = 27)

Mean age (months)	59.17 \pm 61.90(4 months to 26 years)
Mean pre op hemoglobin (g/dl)	16.66 \pm 3.30 (11.90-25.5)
Mean pre op weight (Kg)	15.37 \pm 10.49 (4.3 - 53)
Mean pre op O2 saturation	71 \pm 5.16% (62-80%)
Mean pre-op PA pressure (mmHg)	12.62 + 2.30 (8 to 18)
Postoperative parameters	
Mean duration of ventilation (hours)	19.04 \pm 7.72 (4-42)
Mean pericardial drainage (ml)	353.16 \pm 277.02 (80-1075)
Mean blood products used (ml)	174.21 \pm 291.66 (0-1300)
Mean pleural drainage (ml)	179.67 \pm 87.04(45-1135)
Mean intensive care stay (hours)	70.45 \pm 8.94 (38-210)
Mean hospital stay (days)	12.23 \pm 3.21 (7-15)

Values were expressed as mean \pm SD (Range)

patients who had BDG shunt on cardiopulmonary bypass or local veno-atrial bypass were excluded from the study. Main criteria for performing BDG using CPB included the requirement of associated atrioventricular valve repair, branch pulmonary artery reconstruction and severe preoperative hypoxemia (O_2 saturations $< 60\%$). Clamp and sew off pump BDG was offered as an initial procedure to patients having single ventricle anomaly who were more than 04 month of age with reduced pulmonary blood flow and adequate branch pulmonary arteries. It was also offered to patients who had undergone initial palliation with pulmonary artery banding or Modified Blalock Taussig Shunt (MBTS) at around 09 months of age. Patients were counseled in detail but the exact timing depended upon patient's preference, ease and affordability.

and cardiac catheterization was carried out in all the patients before proceeding to BDG. Echocardiography was the main diagnostic tool and focused on 1) Segmental analysis, 2) Atrioventricular valvular competence, 3) Pulmonary artery sizes and pulmonary outflow tract obstruction, 4) Systemic outflow obstruction, 5) Restriction across atrial or ventricular septum and 6) Identification of patent ductus arteriosus (PDA) or any other extra source of pulmonary blood flow. Further testing like abdominal ultrasonography for spleen and Howell-Jolly bodies on blood smear was done when warranted as in heterotaxy syndromes. Cardiac catheterization was done to 1) Measure pulmonary artery pressures, 2) Calculate pulmonary vascular resistance 3) Measure McGoon ratio (Sum of the diameters of the branch pulmonary arteries measured immediately proximal to hilar branches, divided

by the diameter of the descending aorta at the level of the diaphragm), 4) Evaluate branch pulmonary arteries for stenosis that require patch augmentation at the time of BDG, 5) Assess ventricular function and atrioventricular valve competence and 6) Identify major aorto-pulmonary collaterals (MAPCAS). If significant MAPCAS were found, those were closed before surgery in catheterization lab. If mean pulmonary artery pressure was more than 18 mmHg, temporary balloon occlusion of the main pulmonary artery was done to obstruct the antegrade flow through pulmonary valve and then pulmonary artery pressures were measured again. Important prerequisite for proceeding to BDG are given in table-1.

Informed written consent was obtained for all the patients. All the procedures were done under general anaesthesia. In addition to routine intraoperative monitoring, a 20 G peripheral venous cannula was placed in internal jugular vein of all patients for monitoring of central venous pressure during and after the procedure. A separate triple lumen venous catheter was inserted in femoral vein for the institution of IV fluids and vaso-active drugs. CPB apparatus was always kept ready to function in case of emergency. Patients were not cooled actively and core temperature was allowed to drift to 35-36°C. Arterial blood gases were analyzed after intubation, during the procedure if needed and after the completion of the procedure. All procedures were performed through median sternotomy. The SVC was dissected and completely skeletonized from its junction with innominate vein to the cardiac end. The azygos vein was dissected but not ligated at this stage to achieve some decompression of the proximal segment till the completion of anastomosis. Similarly PDA and / or MBTS if present was identified and dissected but not closed at this time to provide pulmonary blood flow during clamping of the right pulmonary artery. After the dissection of main pulmonary artery and right pulmonary artery till its hilar branches, half dose heparin (150 IU/kg) was administered to achieve

an activated clotting time (ACT) of ≥ 200 seconds. At this stage head end of operating table was elevated (about 20-25 degrees), a fluid bolus of 10-15 ml/kg was given, inspired oxygen concentration was increased to 100% and elective dopamine infusion was started @ 5 μ g/kg/min in order to maintain hemodynamic stability. SVC was now test clamped for about 2 minutes to assess whether patient would tolerate this clamping without significant hemodynamic compromise and fall in transcranial pressure (defined as the difference between the systolic arterial pressure and the mean jugular venous pressure). If patient remained hemodynamically stable and transcranial pressure was more than 35 mm Hg, right pulmonary artery was now test clamped for about 2 minutes to assess if patient was able to maintain adequate Oxygen saturations (≥ 60 -65%). If patient remained stable and maintained adequate oxygenation, procedure was continued as planned otherwise SVC and pulmonary artery clamps were removed and procedure was completed on CPB. Once the decision to continue with clamp and sew technique was made, SVC was ligated just above the cardiac end avoiding the SA node and subsequently divided and over sewn (figure 1A). The right pulmonary artery was opened horizontally at its superior aspect matching to the size of SVC opening. The distal end of the SVC was now anastomosed to the pulmonary artery in an end to side fashion using continuous suture (figure 1B). The SVC and right pulmonary artery clamps were released after completion of anastomosis (figure 1C). In case of bilateral SVCs separate anastomosis was done on left pulmonary artery. To avoid stealing of blood from SVC to inferior vena cava (IVC), azygos vein was now doubly clipped and interrupted. PDA was also interrupted at this stage. In case of left SVC, care was taken to interrupt the hemi-azygos vein as well.

Inflow occlusion was used to perform atrial septectomy if required. For this head end of the table was lowered and SVC and IVC were clamped. A short incision was made in the right

atrium and very quickly as much inter atrial septum was incised as was possible to make a big inter-atrial communication. Right atrial opening was controlled by a vascular clamp and caval clamps were removed. Atrial incision was now closed with prolene suture. Left pulmonary artery stenosis, if present was dealt after making the right BDG shunt. If Glenn pressures were < 15 mm Hg, antegrade flow through the main pulmonary artery was left intact, otherwise main pulmonary artery was transected and proximal stump was over sewn and distal stump was closed with an autologous pericardial patch. As a routine four pacing wires (02 each on right atrium and right ventricle) were placed. Due to high chances of pleural effusion both the pleura were opened and chest drains were placed in both the pleural cavities along with mediastinal drain. The SVC pressure, systolic blood pressure, clamping time and oxygen saturation before, during and after release of SVC clamp were recorded.

In ICU each patient was evaluated for cardiac rhythm, central venous pressure, systemic blood pressure, and perfusion. Chest X-ray and echocardiography were performed as early as possible to evaluate the repair. Heart rate and rhythm, central venous pressure, blood pressure, oxygen saturation and urine output were monitored continuously. Routine blood chemistry was performed and arterial and venous blood gases were monitored periodically (every 02-03 hrs) along with electrolytes and lactate levels. Chest drainage was monitored every hour. Heparin in a dose of 10 IU/Kg was started after the chest drainage was noted to be minimal. Broad spectrum antibiotic cover was provided. Head end of the bed was raised to 35-40° to help promote flow into the BDG. Sildenafil was started in patients with relatively high pulmonary artery pressures and high Glenn pressures (> 18 mm Hg). Patients were weaned from ventilation as soon as possible if all parameters were within acceptable levels. Based on hemodynamics, inotropic support was gradually withdrawn, chest and mediastinal

drains were removed when there was minimal or no drainage for at least 06 hrs. Persistent chest tube output was evaluated for evidence of a chylothorax. Once documented, chylothorax was managed accordingly. Complete neurological assessment including cognitive function was done on all patient and the results were compared with the preoperative examination. Protocol was made that if any postoperative neuro-cognitive impairment was noticed, patient would undergo a computerized tomography scan of the head and expert help of pediatric neurologist would be sought. Postoperative ventilation time (hours), length of stay in intensive care (hours) were also recorded for all the patients. Detailed echocardiographic evaluation of the cardiac repair was done postoperatively and before the patients were discharged from the hospital. All the patients were started on aspirin (5mk/kg/day) which was continued indefinitely.

Statistical analysis was done using Statistical package for social sciences (SPSS) version 20. Qualitative variables were presented as frequencies and percentages while quantitative variables were presented as mean and standard deviation with range. Paired 2-tailed t test was used to compare pre and post results. A p-value < 0.05 was considered as significant.

RESULTS

A total of 29 patients were planned for clamp and sew technique during the study period. However, 2 patients were converted to regular BDG with CPB support due to hemodynamic instability on test clamping of SVC or pulmonary artery. Remaining 27 patients underwent BDG with clamp and sew technique and were included in the study for further analysis. Seventeen (63%) were males. The demographics and preoperative characteristics are given in table 2. Twenty three (85.2%) patients had unilateral BDG while 04 (14.8%) patients had bilateral BDG. Two (7.4%) patients had previous MBTS and one (3.7%) patient had previous pulmonary artery banding. Eight (29.6%) patients

underwent inflow occlusion atrial septectomy after completion of the procedure was $14.29 \pm$

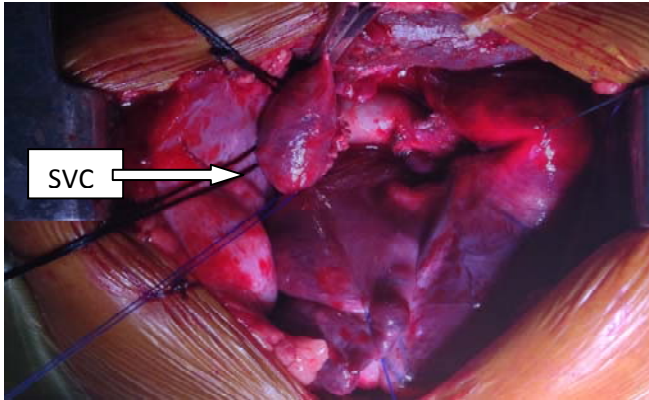


Fig-1: A Clamp has been applied on right superior vena cava and cavo-atrial junction being ligated.

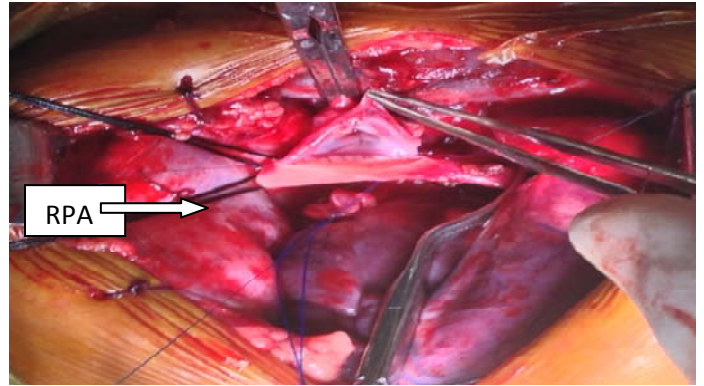


Fig.1B-Right SVC to Right PA anastomosis in progress, posterior wall has already been anastomosed.

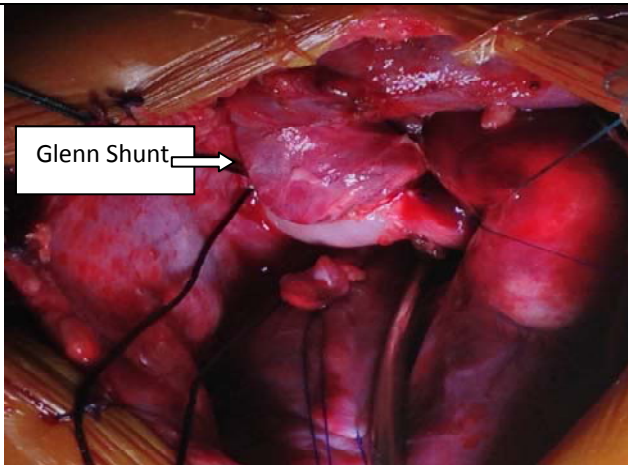


Fig.1C-BDG Glenn shunt after completion and removal of clamps.

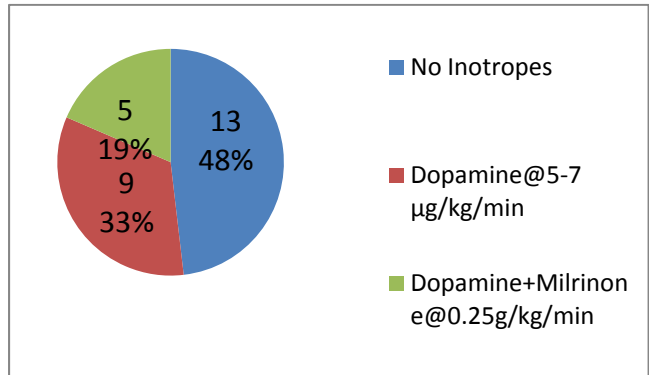


Figure-1: Description of inotropes used among patients (n = 27).

and one (3.7%) patient had patch augmentation of left pulmonary artery along with BDG. The average rise of central venous pressure on clamping the SVC 29.21 ± 6.13 mm Hg ranged from 19–43 mm Hg with a mean transcranial pressure gradient of 45.35 ± 14.46 mm Hg ranged from 36–75 mm Hg. The mean SVC clamp time was 14.32 ± 3.39 minutes with a range of 11–21 minutes. Antegrade pulmonary blood flow was left in 16 (59.2%) patients. Mean Glenn pressure

2.53 mm Hg ranged from 12–18 mm Hg. There was significant improvement in postoperative oxygen saturations from $71 \pm 5.16\%$ preoperatively to $86.07 \pm 2.71\%$ ($p < 0.001$) postoperatively. All the patients were in sinus rhythm except one (3.7%) who remained in nodal rhythm for initial 03 hours. Inotropes were used in 14 (51.8%) patients (Figure-1). None of the patients had heart blocks or required pacing.

Other important post-operative parameters are given in table-2.

There was no neurological event in the ICU in any of the patients and they made a good postoperative recovery. Post-operative echocardiography showed a well-functioning BDG without any narrowing of SVC-pulmonary artery anastomosis in all patients. There were no reoperations and no 30 day operative mortality in this study.

DISCUSSION

The classic Glenn shunt was initially performed by William Glenn in 1958 through a thoracotomy with partial occlusion of the SVC without CPB¹³. However, temporary occlusion of SVC during anastomosis can lead to increased intracranial pressure and subsequently may cause neurological injury. This was demonstrated by Rodriguez et al who reported reduced cerebral blood flow velocities, and global electroencephalographic slowing after transient obstruction of the SVC which returned to normal when the obstruction was relieved⁸. This fear led many surgeons to perform BDG with either CPB or local bypass. BDG can very safely be performed with CPB support but it has got its inherent problems mostly due to complement activation that can result in increased pulmonary vascular resistance, increased fluid sequestration and depressed myocardial function which may affect the clinical outcome of the surgery badly^{14,15}. Also, it is associated with higher cost owing to additional equipment and personnel required.

The problem of increase in cerebral venous pressure after clamping the SVC to a major extent can be avoided by establishing a temporary local decompressing bypass between SVC and right atrium or pulmonary artery^{2,9-12}. These techniques are less hazardous than conventional CPB, but still expose blood to extra-corporeal circuit that can cause complement activation¹⁴. Use of veno-atrial local bypass for decompression of SVC is one of the most commonly employed techniques. In this technique temporary SVC to RA shunt is

made using standard vena caval cannulae. In case of bilateral SVCs this temporary shunt can usually be avoided all-together. Abid et al described this technique in detail and reported there excellent results at AFIC/NIHD². Similarly Luo et al. reported their results of off-pump Glenn operation in 28 patients using temporary SVC-right atrial shunt. In 8 patients with bilateral SVC, they did not use any shunt. They reported no neurological complications in their patients. Comparing these results with 35 patients who had earlier undergone Glenn procedure on CPB, they demonstrated that the off-pump group showed better postoperative results in terms of lower pulmonary artery pressure, shorter duration of ventilatory support, and less plural fluid drainage⁹. Some centers use temporary veno-pulmonary bypass to achieve decompression. In this technique temporary shunt is constructed between SVC and main pulmonary artery or contralateral branch pulmonary artery. Murthy and colleagues¹⁰ first described the technique of veno-pulmonary shunt in 1999 employing two standard right-angle cannulae. Veno-pulmonary shunt functions as a modified Glenn's shunt while SVC is clamped for anastomosis and oxygen saturation is actually increased during this period. SVC to main pulmonary artery shunt obviously cannot be used in patients with main pulmonary artery atresia or hypoplasia. In such cases contralateral branch pulmonary artery can be used. This can cause distortion of the pulmonary artery rendering it unsuitable for future Fontan repair. Tireli et al¹¹ reported their series of 30 patients who had the Glenn operation performed without CPB. They used both veno-atrial and veno-pulmonary techniques in their patients randomly and reported that the most effective caval drainage was present when the shunt was constructed between SVC and left pulmonary artery. Liu et al¹² described their series of 20 patients of off-pump BDG using veno-atrial or veno-pulmonary shunts. They reported that BDG without CPB is reasonably safe if SVC pressure after clamping remains at less than 30 mm Hg

and clamping time is less than 30 minutes. There were no postoperative neurological complications in their study patients.

Another option is to perform BDG without CPB or local bypass by simply clamping the SVC and pulmonary artery and fashioning an end to side anastomosis between the two. This technique is also called "clamp and sew technique"⁷. The problem with this technique is that when clamp is applied on SVC one third of the circulation is compromised and similarly when clamp is applied to pulmonary artery half of the oxygenation source is also taken down. Moreover, transient rise in venous pressure in head and neck region after SVC clamping can also compromise cerebral perfusion resulting in deleterious effects on brain⁸. However these problems can be dealt with by adopting certain measures to keep adequate hemodynamics and cerebral perfusion pressures during the procedure and performing anastomosis quickly. Jahangiri and associates¹⁶ in 1999 described this technique in detail and proved that BDG can safely be performed without local decompression or CPB. They reported their series of seven patients who underwent BDG shunt without the use of CPB or local decompression technique. The SVC pressure during the clamp ranged from 19–65 mm Hg (median 26 mm Hg). They attempted to maintain the cerebral perfusion by maintaining transcranial pressure (defined as the difference between the systolic arterial pressure and the mean jugular venous pressure) at a minimum of 30 mm Hg. This was done using inotropic agents whenever required. They did not report any neurological injury. Hussain and associates¹⁷ in 2007 also reported similar results.

In our patients, though we did not use any conventional decompressive technique, we clamped the SVC below the insertion of azygos vein in order to decompress the proximal SVC segment to some extent. We conducted the operation with the head-end of the operating table elevated so that the venous drainage would find alternative pathways and the proximal caval pressure be kept as low as possible. We electively

used dopamine and loaded the patients with plenty of volume to maintain adequate hemodynamics after SVC clamping and attained good (> 35 mm Hg) transcranial pressure. The mean transcranial pressure gradient in our patients was 45.35 ± 14.46 mm Hg (range, 36–75 mmHg). The clamp time in our study had been relatively short (14.32 ± 3.39 minutes) and we did not encounter any brain injury. Our results are in accordance with the results reported by other researchers^{7,16,17}. In our opinion, it is vital to keep the clamp time as short as possible while also ensuring that there is no compromise in the making of the shunt. This is possible by properly planning and executing the exact sequence of the steps.

None of the patients had any hemodynamic compromise or significant decrease in systemic oxygen saturation during the procedure. In our patients, we ensured adequate baseline oxygen saturation (60–65%) and an acceptable saturation on test clamp of pulmonary artery. We excluded patients with saturation $< 65\%$ on test clamp.

Antegrade pulmonary blood flow was left intact in 16 patients rendering the flow pulsatile. Different authors have reported the usefulness of pulsatile BDG^{18,19}. Preserving additional pulsatile pulmonary blood flow provides additional flow for the growth of branch pulmonary arteries with higher oxygen saturations. Antegrade pulmonary blood flow can also reduce the incidence of pulmonary arterio-venous malformations (PAVM), as it allows "Hepatic factor" to be available in pulmonary arterial blood. Absence of hepatic factor has been suggested to be the cause of development of these PAVMs. At the same time, there is a disadvantage in the terms of relatively higher Glenn pressures and less volume unloading of the single ventricle. The main pulmonary artery was disconnected routinely in patients with borderline pulmonary artery pressures (mean > 15 mm). Surgical atrial septectomy under normothermic caval in flow occlusion is very helpful for patients who have a restrictive atrial septum and require an atrial septectomy²⁰. The advantage of avoiding CPB in

this setting is in large part related to the effects of CPB^{14,15}. The procedure requires surgical experience and involvement of a good anaesthetist. Otherwise, a brief period of CPB for performing the procedure is not an unreasonable alternative. In general, the postoperative management of these patients after off pump BDG had been similar to that after BDG with CPB. That is, all treatment should aim at decreasing the pulmonary vascular resistance and accelerating the SVC return. In our experience, these patients generally do well in terms of ventilation time, requirement of inotropes and hospital stay. As none of our patients showed any signs of neurological deterioration during entire hospital stay as well as in follow up period neither any of their parents reported about abnormal behavior of their children, we assume clamping SVC for short period is devoid of any significant brain damage. This was also reinforced by repeated neurological assessment by our pediatrician in each follow up visit. There is significant cost reduction when these procedures are performed off bypass. The cost of performing a Glenn procedure on CPB is about Rs 310,000 at our center, while it is only about Rs 150,000 when done without CPB. This is a significant benefit for these patients, as they have to undergo a further procedure in future. To conclude, bidirectional Glenn shunt without cardiopulmonary bypass is a safe procedure in selected patients. It avoids cardiopulmonary bypass related problems and is economical, with good results.

REFERENCES

- Zaidi SSN, Saleem K, Khan I, Bakht N, Ahmed I. Experience of fontan surgery at Armed Forces Institute of Cardiology / National Institute of Heart Diseases (AFIC-NIHD). Pak Armed Forces Med J Apr - Jun 2011;61(2):160-3
- Hussain A, Saleem K, Khan I, Rashid A, Ahmed I, Younus U. Bidirectional Glenn shunt without cardiopulmonary bypass. J Coll Physicians Surg Pak Nov 2009;19(11):682-5
- O'Brien P, Boisvert JT. Current management of infants and children with single ventricle anatomy. J Pediatr Nurs 2001 Oct; 16(5): 338-50
- Fisher DJ, Geva T, Feltes TF, Cecchin F, Nihill MR, Grifka R, et al. Life long management of patients with a single functional ventricle. A Protocol. Tex Heart Inst J 1995; 22: 284-95
- Lee JR, Choi JS, Kang CH, Bae EJ, Kim YJ, Rho JR. Surgical results of patients with a functional single ventricle. Eur J Cardiothorac Surg 2003 Nov; 24(5): 716-22.
- Lamberti JJ, Spicer RL, Waldman JD, Grehl TM, Thomson D, George L, et al. The bidirectional cavopulmonary shunt. J Thorac Cardiovasc Surg 1990; 100: 22-30.
- Bhan A. Off-pump bi-directional Glenn shunt: How I do it? Ann Pediatr Cardiol 2008 Jul-Dec; 1(2): 131-4.
- Rodriguez RA, Cornel G, Semelhago L, Splinter WM, Weerasena NA. Cerebral effects in superior vena caval obstruction: the role of brain monitoring. Ann Thorac Surg 1997; 64: 1820-22
- Luo X, Yan J, Wu Q, Yang K, Xu J, Liu Y. Clinical application of bidirectional Glenn shunt with off-pump technique. Asian Cardiovasc Thorac Ann 2004; 12: 103-6.
- Murthy KS, Coelho R, Naik SK, Thomas PW, Cherian KM. Novel technique of bidirectional Glenn shunt without cardiopulmonary bypass. Ann Thorac Surg 1999; 67: 1771-4
- Tireli E, Basaran M, Kafali E, Harmandar B, Camei E, Dayioglu E, et al. Peri-operative comparison of different transient external shunt techniques in bidirectional cavo-pulmonary shunt. Eur J Cardiothorac Surg 2003; 23: 518-24
- Liu J, Lu Y, Chen H, Shi Z, Su Z, Ding W. Bidirectional Glenn procedure without cardiopulmonary bypass. Ann Thorac Surg 2004; 77: 1349-52
- Glenn WWL. Circulatory bypass of the right side of the heart. IV. Shunt between superior vena cava and distal right pulmonary artery - report of clinical application. N Engl J Med 1958; 259: 117-20
- Kirklin JK, Westaby S, Blackstone EH, Kirklin JW, Chenoweth DE, Pacifico AD. Complement and the damaging effects of cardiopulmonary bypass. J Thorac Cardiovasc Surg 1983 Dec; 86(6):845-57
- Murphy GJ, Angelini GD. Side effects of cardiopulmonary bypass: what is the reality? J Card Surg 2004 Nov-Dec; 19(6): 481-8
- Jahangiri M, Keogh B, Shinebourne EA, Lincoln C. Should the bidirectional Glenn procedure be performed through a thoracotomy without cardiopulmonary bypass? J Thorac Cardiovasc Surg 1999; 118: 367-8
- Hussain ST, Bhan A, Sapra S, Juneja R, Das S, Sharma S. The bidirectional cavopulmonary (Glenn) shunt without cardiopulmonary bypass: is it a safe option? Interact Cardiovasc Thorac Surg 2007; 6:77-82
- Calvaruso DF, Rubino A, Ocello S, Salviato N, Guardi D, Petruccielli DF, et al. Bidirectional Glenn and antegrade pulmonary blood flow: temporary or definitive palliation? Ann Thorac Surg 2008; 85: 1389-96
- Yoshida M, Yamaguchi M, Yoshimura N, Murakami H, Matsuhisa H, Okita Y. Appropriate additional pulmonary bloodflow at the bidirectional Glenn procedure is useful for completion of total cavopulmonary connection. Ann Thorac Surg 2005; 80:976-81
- Jonas RA, Castaneda AR, Freed MD. Normothermic cavalinflow occlusion. Application to operations for congenital heartdisease. J Thorac Cardiovasc Surg. 1985; 89: 780-6