Veno-venous shunt-assisted cavopulmonary anastomosis

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ABSTRACT

Objective : **The bidirectional Glenn shunt is commonly performed under cardiopulmonary bypass for conditions that lead to a single ventricle repair. We report our experience of bidirectional Glenn shunt done without cardiopulmonary bypass.**

Methods: : **Between June 2007 and May 2009, 186 consecutive patients underwent off-pump bidirectional Glenn shunt for a variety of complex cyanotic congenital heart defects. Age ranged from four months to six years and the median weight was 11.17 kg (range 4.3 - 18). After systemic heparinization, the procedure was done by creating a temporary shunt between the innominate vein and the right atrium connected across a three way connector for de-airing. Fifty one patients had bilateral cavae. All cases underwent complete clinical neurological examination.**

Results : **No case required conversion onto cardiopulmonary bypass. Four patients (2.14%) died in the immediate postoperative period. The mean internal jugular venous pressure on clamping the decompressed superior vena cava was 24.69 ± 1.81 mm Hg. There was no intra-operative hemodynamic instability and oxygen saturation was maintained at more than 70% throughout. Post Glenn shunt, the saturations improved to mid 80s. Seventy four cases had documented forward flow across the pulmonary valve. The mean duration of ventilation was 10.17 ± 8.96 hours and there were no neurological complications. Six patients (3.22%) developed pleural effusions, 4 patients (2.15%) had nodal rhythm and 9 patients (4.83%) had superficial sternal wound infection.**

Conclusions : **Our results show that off-pump bidirectional Glenn shunt can be done safely in patients not requiring associated intra-cardiac correction. It avoids cardiopulmonary bypass and its related complications, is economical and associated with excellent results. In our opinion, this is the largest series of off-pump bidirectional Glenn shunt in the literature.**

Keywords : Bidirectional cavopulmonary shunt, cardiopulmonary bypass

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INTRODUCTION

Bidirectional Glenn shunt (BDGS) was introduced in 1972[1] and is a commonly performed procedure for a variety of cyanotic congenital heart conditions that eventually lead to a single ventricle route and also as part of a one and a half ventricle repair in patients with hypoplastic right ventricle and Ebstein's anomaly. The end-to-side anastomosis of the superior vena cava (SVC) to the right or left pulmonary artery may be converted to a total cavopulmonary connection later and effectively increases arterial blood oxygen saturation and decrease the ventricle volume overload. BDGS is usually performed on cardiopulmonary bypass (CPB). However, the growing concern of cost escalation related to CPB and its associated complications led us[2] and others to report creation of off-pump BDGS either assisted or unassisted with a temporary shunt.[3] To our knowledge, this is the largest single institute experience of shunt assisted off-pump BDGS to date and we report our technique and results for the last two years.

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METHODS

Between June 2007 and June 2009, 1825 cardiac surgical procedures were done at Innova Children's Heart Hospital, Secunderabad. One hundred eight six of them were bidirectional cavopulmonary anastomosis done without the use of cardiopulmonary bypass. There were 115 male and 71 female children and the age ranged from four months to six years. The median weight was 11.17 kg (range 4.3 - 18). The disease spectrum is as listed in Table 1. Four patients had a pulmonary artery band and eight patients had a systemic-pulmonary shunt prior to BDGS. Fifty one cases had bilateral cavae and did not require shunt placement. All patients had a standard transthoracic echocardiographic examination and in some cases cardiac catheterization. Decision to do an off-pump shunt-assisted procedure was based on the size of the branch pulmonary arteries (PA) and adequacy of inter-atrial communication. Patients requiring intracardiac corrections were excluded from the study group. Prior pulmonary artery banding and confluence stenosis was not considered a contraindication. All preoperative cases underwent clinical neurological examination by an in-house pediatrician.

Technique

The surgery was conducted under general anesthesia and through a standard median sternotomy. The intra-operative management included monitoring of electrocardiogram, oxygen saturations, invasive blood pressure and end-tidal carbon dioxide levels. Temperature probe was used to record the nasopharyngeal temperature. A single lumen central venous neck line was placed to monitor the pressure within the Glenn shunt and separate multi-port femoral venous line was placed to infuse drugs and measure left atrial pressure. Arterial blood gas was analyzed at baseline, after tracheal intubation, whilst the cava was clamped and half an hour after de-clamping. Intraoperatively, PA size was assessed and direct pulmonary artery pressure is estimated. The SVC and the left innominate vein were dissected completely taking care to stay closer to the cava and hence keeping lymphatic channels safe. Similarly, the concerned branch PA was dissected up to the hilum and looped. In patients presenting with nodal rhythm and those on pre-procedure beta blockers, pacing wires were placed electively prior to starting dissection. Patent aortico-pulmonary shunts and ductus arteriosus were identified, dissected and left undisturbed at this stage of the procedure. Marker stitches were placed on the site of possible division over the anterior aspect of the SVC. The azygous vein was ligated and divided between ligatures. Purse-string sutures were placed on the innominate vein at its junction with the SVC and a cannula was selected based on its size. Another purse-string suture was placed on the right atrial appendage. The branch PA was trial clamped for a few minutes to check for changes in arterial oxygenation. After systemic heparinization [1mg/kg] to keep activated clotting time more than 200 seconds, the innominate vein and the right atrial appendage were cannulated, connected through a three-way connector and carefully de-aired [Figure 1]. With the shunt open and the head-end elevated, the SVC was clamped at right atrial end and near the innominate insertion and divided just below the marker stitch. The proximal end was suture closed and the strings used to retract it away from the branch PA. The branch PA was isolated within a Cooley clamp and opened between stay sutures. The SVC was anastomosed to the branch PA with continuous prolene suture keeping the divided azygous end as a posterior landmark. The clamps were released to allow the Glenn shunt to flow. In case of branch stenosis and borderline branches, the SVC was placed more towards the confluence. Post Glenn shunt, the aortico-pulmonary shunt and the ductus arteriosus were ligated. A decision was made to allow some forward flow across the pulmonary valve based on the Glenn pressures. Hemostasis was achieved after decannulation and chest was closed as routine with chest drains. In cases with bilateral SVCs, shunt decompression was not required as one shunt was constructed at a time, allowing the other to decompress.

Table 1: The disease spectrum of study group

Lesions	Number of patients
Single ventricle substrates	84
DORV/TGA/non-routable VSD/PS	80
Unbalanced AVSD / PS	22

RESULTS

There were four deaths during the study period (2.14 %).

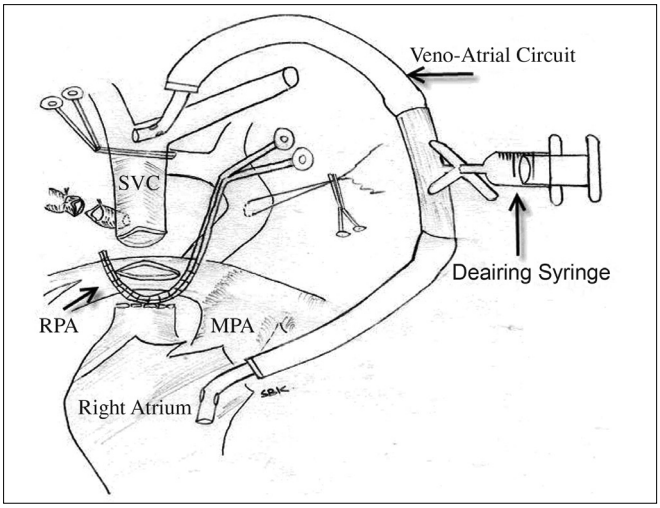

Figure 1: The veno-venous shunt away from the surgeon and the divided SVC- RPA anastomotic site. SVC: Superior vena cava, RPA: Right pulmonary artery, MPA: Main pulmonary artery

The mean rise in CVP with the clamp on was 24.69 ± 1.81 mm Hg. Seventy four cases documented forward flow across the pulmonary valve. The average post-procedure saturation was 85.34 % and the mean duration of ventilation was 10.17 ± 8.96 hours. None of the cases required conversion onto cardiopulmonary bypass. Six patients (3.22%) developed pleural effusions requiring drainage, four patients (2.15%) had nodal rhythm requiring atrial pacing, four patients were re-explored for bleeding (two for tightening the PA band) and nine (4.83%) had superficial sternal wound infection. There was no clinically recognizable neurological insult recorded and all children were neurologically normal at the time of discharge from hospital.

DISCUSSION

The conduct of off-pump BDGS without proximal decompressing shunt can be associated with significant elevation of the proximal SVC pressure, decreased cerebral blood flow and neurological damage.[4] Jahangiri *et al*.[3] reported the feasibility of unassisted off-pump BDGS without any neurologic deficits by attempting to maintain the cerebral perfusion (transcranial pressure) which they defined as the difference between the systolic arterial pressure and the mean jugular venous pressure, at a minimum of 30 mmHg. Whether performing off-pump BDGS with such a strategy protects the cerebrum is still debated. The high CVP may cause a concern about the long-term deleterious effect on the cognitive functions of the child. The authors believe that their patients did not have neurologic complications and, therefore, this was considered as a reasonable method of performing the Glenn shunt.[4] With increasing SVC pressure on clamping, one study showed significantly decreased oxyhemoglobin in brain tissue with near-infrared spectroscopy [5] and other study showed 50% reduced blood flow velocity in the middle cerebral artery[6] with significant changes in the electroencephalogram.[7] To avoid significant rise in SVC pressure on clamping and its adverse effects, it seems logical to use a temporary veno-venous shunt to decompress the SVC and improve cerebral perfusion. Our group [2] along with others [2, 3, 5, 8-12] had reported the safety of performing off-pump BDGS using various techniques to drain the SVC blood during clamping. Lal and Mahant[9] reported that BDG could be done without using cardiopulmonary bypass. In this technique, even though they did not use CPB, per se, they had to employ the roller pump for draining the blood, and also required a perfusionist for perfusion.

A temporary shunt with a suitable size cannula effectively decompressed the SVC as shown in our study. Our technique of cannulating the innominate vein near to its SVC junction helped drain the SVC effectively and avoided the possibility of narrowing the SVC. The whole circuit, which lies away from the surgeon, was placed in-plane with the heart on a rolled towel with the three-way connector pointing upwards. This, along with head-up position, facilitated adequate decompression of the SVC and provided good room for constructing the anastomosis. Postoperative chylothorax and phrenic nerve dysfunction were infrequent with our technique and are prevented by dissecting close to the SVC and avoiding unnecessary tissue planes.

Intra-operative co-ordination with the anesthesiologist remained the mainstay of a successful shunt assisted off-pump BDGS. The temperature was allowed to drift to 33-34 degrees centigrade which probably assisted in cerebral protection. Inotropes and volume replacement were used to maintain adequate cerebral flow and a higher transcranial pressure gradient during clamping. Sudden onset arrhythmias were aggressively managed with systemic anti-arrhythmic agents and in some cases with selective atrial cardioversion. Elective pacing wire placement and atrial pacing in cases with nodal rhythm and instillation of topical lidocaine helped in abating arrhythmias and maintaining cardiac output. Hypoxic episodes were managed by escalating the fraction of inspired oxygen and optimizing inotropes and colloids to enhance the mean arterial pressure and hence flow to the lungs. Patients with functioning aortic-pulmonary shunts and patent ductus arteriosus form a favorable group as the shunt provided alternate flow to the lungs whilst the Glenn shunt is constructed. Concerns with BDGS including progressive desaturation, disparity with patient size, and pulmonary vascular changes such as arteriovenous malformations were reduced by allowing antegrade flow across the pulmonary annulus. The forward flow provided pulsatility thyereby, promoting PA growth and diverted hepatic venous blood to both lungs.

Postoperative management was aimed at decreasing the pulmonary vascular resistance and accelerating the SVC return. In patients with higher Glenn pressures, ino-dilators helped in lowering the mean PA and left ventricular end-diastolic pressures. Off-pump BDGS facilitated early extubation as observed in our study and the total duration on respirator was reduced. An unprimed pump should always be available as a standby though no case in this series required conversion onto CPB. Valve regurgitation greater than moderate, hypoplastic pulmonary artery branches and restrictive inter-atrial septum requiring septectomy should be corrected with the support of cardiopulmonary bypass. Assessment of the neurological outcome secondary to physiological and biochemical changes that alter neurological function has always been difficult. A myriad of tests required to prove cerebral dysfunction were not practical in our setup. We relied on clinical aspects and at the time of discharge all our cases had a normal clinical neurological examination. All patients were started on

heparin for the first 24 hours post surgery and were subsequently covered with aspirin for rest of the life. Early extubation, aggressive diuresis and salt restricted diet were a regular part of postoperative care.

To conclude, our technique of veno-venous shunt-assisted off-pump BDGS obviates the need for bypass, its adverse effects and additional personnel. It is safe, reproducible, economical, and simple to set up with limited hardware. Apart from avoiding blood transfusion, it is associated with excellent results and with a few postoperative complications.

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