Pulmonary Artery to Descending Thoracic Aorta Bypass: An Alternative Approach to Vascular Access for Open Heart Surgery

William J. Gil, Allan M. Lansing and Patricia H. Gornet
Humana Heart Institute International
Louisville, KY

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Abstract

(*J. Extra-Corpor. Technol.* 19[3] p. 372–375 Fall 1987, 8 ref.) A variety of conditions can increase the mortality and morbidity of a midsternotomy approach for cardiothoracic surgery. Among these complicating conditions are reoperations, sternal infections and past mediastinal radiation therapy. In the face of the inherent risks of midsternotomy in these situations an alternate, left thoracotomy approach, has successfully been employed.

The left thoracotomy approach for cardiopulmonary bypass necessitates a unique cannulation technique. The pulmonary artery is cannulated for venous return to the cardiopulmonary bypass circuit. Systemic blood flow to the patient is via the descending thoracic aorta. The femoral artery may also be used for arterial access.

The physiological principles that allow the pulmonary artery to be used as the venous cannulation site, the cardiothoracic procedures this may avail itself to, and the safety techniques used when this approach is employed will be discussed. Several cases in which this technique was used will also be reviewed.

Introduction

For many years experimental[1,2] and clinical evidence[3] has supported the ability of the central venous pressure to maintain adequate blood flow through the lungs when right ventricular dysfunction is present. This blood flow can be maintained indefinitely in the face of normal pulmonary artery pressures.[4]

Direct communications to: William J.Gil, B.S., C.C.P., 2390 Bellwood St., Pittsburgh, PA 15237

Many of the corrective and palliative procedures used for the treatment of congenital cardiac defects are based on this evidence. The Glenn Procedure[5,6,7] (Figure 1) and the Fontan Procedure[8] (Figure 2) bypass the right ventricle, allowing the central venous pressure to maintain the flow of blood through the lungs. The documented success of bypassing the right heart lead us to the conclusion that the pulmonary artery could be used as a cannulation site for venous return to the extracorporeal circuit. This method of cannulation was reserved by us for that group of patients who may be subject to increased risk from a median sternotomy incision. Arterial cannulation was via the descending thoracic aorta or left femoral artery. This cannulation technique has been employed successfully in a number of high risk patients. We will present two of these cases.

Case Report 1

A 13-year-old male was admitted for reoperative surgery for placement of a valved conduit from the apex of the left ventricle to the descending thoracic aorta. His initial diagnosis at birth was congenital pul-

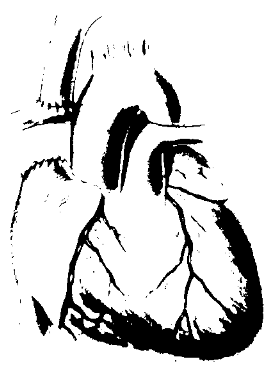

Figure 1: Glenn procedure: End to side anastomosis of the superior vena cava to the right pulmonary artery.

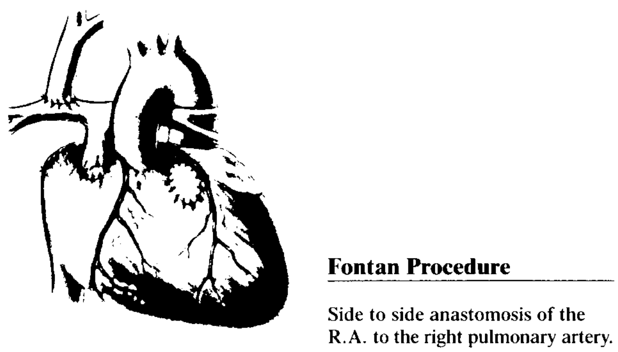

Figure 2: Fontan procedure: Side to side anastomosis of the right atrium to the pulmonary artery.

monic and aortic stenosis with congestive heart failure. He had previously undergone a series of operative procedures to correct his congenital cardiac defects. His past surgical procedures are as follows: 1) at 20 months of age, excision of the pulmonary valve and aortic valvotomy, cannulation for cardiopulmonary bypass (CPB) via the inferior vena cava (IVC) and superior vena cava (SVC) and the ascending aorta. 2) at 3 years of age, aortic valve replacement and left and right ventricular outflow tract enlargement with patch graft, cannulation for CPB via the IVC and SVC and the left femoral artery. 3) at 9 years of age, exploration of the aortic valve, cannulation for CPB via the IVC and SVC and the right femoral artery. Each of these procedures was carried out through a median sternotomy incision.

The multiple median sternotomies and the extensive surgical corrections had lead to the development of dense adhesions in the anterior mediastinum. To avoid the adhesions in the anterior mediastinum and the possibility of massive hemorrhage while dissecting out the heart and vessels for cannulation, a left thoracotomy approach with cannulation of the pulmonary artery for venous return to the perfusion circuit was used. Since both femoral arteries were also used in the previous surgeries the descending thoracic aorta was chosen for the arterial cannulation site.

The CPB circuit consisted of a Sarns 7000 modular roller pump[a], Terumo Capiox 3.3m^2 hollow fiber membrane oxygenator and 1000cc venous reservoir[b], Bentley BCR 3500 filtered cardiotomy reservoir[c], Pall 40 micron arterial line filter[d], and polyvinyl chloride tubing with Bentley in-line oxygen saturation meters[c].

a Sarns Inc., Ann Arbor, MI 48103
b Terumo Corp., Tokyo, Japan
c American Bentley, Irvine, CA 92714
d Pall Biomedical Products Corp., East Hill, NY 11548
e Organon Inc., Orange, NJ 07052

The circuit was primed with 5% dextrose and water and Ringers lactate to which was added 50 mEq sodium bicarbonate and 5,000 units of beef lung heparin[e].

A left thoracotomy incision was made and purse string sutures were placed in the pulmonary artery and in the descending thoracic aorta, just above the diaphragm. The patient was heparinized. The pulmonary artery was cannulated with a 28 fr. venous cannula and the descending thoracic aorta was cannulated with an 18 fr. right angle metal arterial cannula (Figure 3). The aortic cannula was positioned to direct retrograde flow toward the cranial vessels.

The cannulas were connected to the CPB circuit and bypass was instituted. The patient was cooled to 30°C, and the heart was placed in ventricular fibrillation. The placement of the left ventricle to descending thoracic aortic valved conduit was accomplished in three steps. First a 20mm right angle apical connecting cannula with graft was inserted into the apex of the left ventricle. Next a partial exclusion clamp was placed on the descending thoracic aorta just distal to the left subclavian artery and a 23 mm valved conduit was anastomosed to the aorta at this site. Then the apical connecting cannula and the valved conduit were anastomosed end to end. As the last anastomosis was completed the fibrillator was removed and the patient was rewarmed. Special care was taken to remove all the air from the conduit and ventricle, and in addition, the patient was maintained in the Trendelenburg position to protect the brain from any air that might remain in the heart. Then the heart was defibrillated. Bypass was continued for 10 minutes, to allow the cardiac action to stabilize, and then was slowly terminated.

Perfusion flow rates ranged from 1.8 to 2.4 liters per minute per square meter of body surface area. After the heart was placed in ventricular fibrillation, no

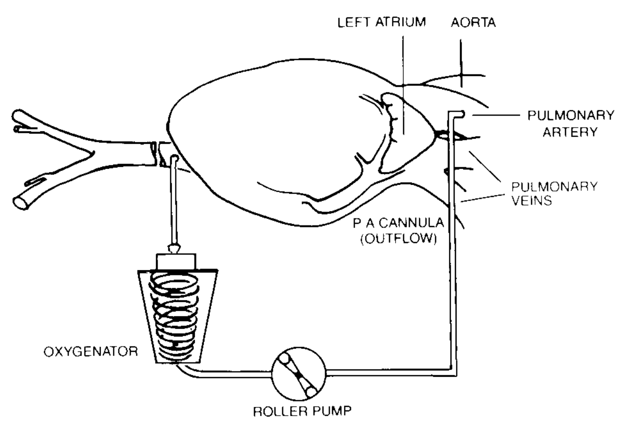

Figure 3: Perfusion circuit: Pulmonary artery to descending thoracic aorta bypass.

reduction in venous return was noted and flows remained unchanged. Arterial pressures ranged from 43 to 56 mmHg pressure. In this case the central venous pressures were not monitored, but venous distension was not noted. Venous oxygen saturations ranged from 68 to 80 percent during bypass (Table 1).

The total bypass period was 78 minutes. Ventricular fibrillation was used for 62 minutes. The patient received two units of packed cells, 300cc ringers lactate, and 100cc of 25% albumin while on bypass.

The patient was discharged from the hospital two weeks after the operation. One month after discharge the patient was allowed to resume full activities.

Case Report 2

A 48-year-old male was admitted for reoperative surgery for resection of a left ventricular aneurysm (LVA). He had previously undergone three median sternotomy incisions. Two of the median sternotomy incisions were for coronary artery bypass grafts. Cannulation for these procedures was via the right atrium and ascending aorta. The third median sternotomy had to be performed due to a bacterial infection of the sternum and mediastinum. He had previously been evaluated for heart transplant or artificial heart implant. It was felt that he was not a good candidate for either of these treatments because of his past history of infection and multiple median sternotomies. For the same reasons, and to avoid disturbing the functioning grafts, it was decided that the LVA should be resected through a left thoracotomy incision. Cannulation for CPB was via the pulmonary artery for venous drainage and the left femoral artery for arterial return.

The CPB circuit used for this procedure was identical with the circuit previously described. However, the size of the oxygenator was increased to 5.4m^2 to accommodate the patient's calculated flow rates.

The left femoral artery was exposed and prepared for cannulation. A left thoracotomy incision was made, a purse string suture was placed in the pulmonary artery, and the patient was heparinized. The left femoral artery was cannulated with a 18 fr. femoral artery cannula. The pulmonary artery was then cannulated with a 40 fr. venous cannula and the cannulas connected perfusion circuit (Figure 4). The patient was then cooled to 28°C and ventricular fibrillation was induced with an electrical current. The LVA was resected and the ventricle closed. The fibrillator was removed as the patient was rewarmed, all air was removed from the left ventricle. CPB was continued until cardiac action stabilized and then the patient was weaned from bypass.

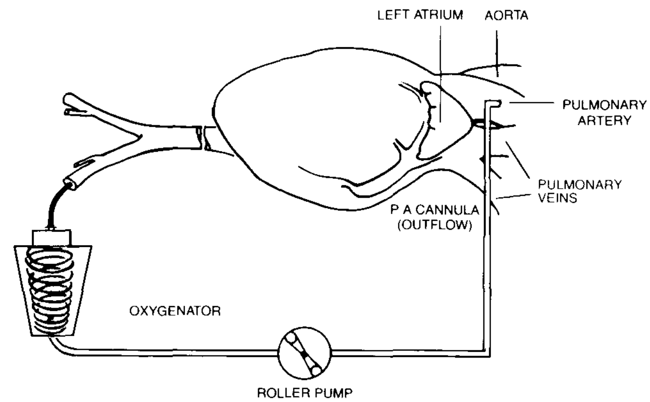

Figure 4: Perfusion circuit: Pulmonary artery to left femoral artery bypass.

Perfusion flow rates ranged from 1.5 to 2.2 liters per minute per meter of body surface area. Again after ventricular fibrillation, no reduction in venous return was noted, flows remained unchanged, and there was no air noted in the venous return line. Arterial pressures ranged from 40 to 79 mmHg pressure. The pulmonary artery diastolic pressure ranged from 0 to 14 mmHg; venous oxygen saturations ranged from 63 to 80 percent during bypass (Table 2).

The total bypass period was 41 minutes. Ventricular fibrillation was used for 34 minutes. The patient received 500cc of Ringers lactate while on bypass. The patient had a difficult postoperative course due to his debilitated condition. He has gradually improved and is doing well at home one year following surgery.

Table 1
Perfusion Parameters: Case #1

	Beating Heart	Fibrillation
Bypass time	16 min	62 min
Flow range	1.8–2.4L/min/M^2	1.8–2.4L/min/M^2
Arterial pressure	49–69 mmHg	43–56 mmHg
PAD pressure	not monitored	not monitored
CVP pressure	not monitored	not monitored
Venous distension	none noted	none noted
Venous O_2 saturation	68–80%	76–80%

Table 2

Perfusion Parameters: Case #2

	Beating Heart	Fibrillation
Bypass time	7 min	34 min
Flow range	1.5–2.2L/min/M^2	1.5–2.2L/min/M^2
Arterial pressure	76–79 mmHg	40–78 mmHg
PAD pressure	12–14 mmHg	0–11 mmHg
CVP pressure	not monitored	not monitored
Venous distension	none noted	none noted
Venous O_2 saturation	68–80%	63–80%

Results

There was no decrease in venous return associated with ventricular fibrillation. Adequate flows were maintained with the absence of venous distension. Drainage of blood from the pulmonary artery decreased pulmonary pressure facilitating the flow of blood through the right ventricle. Venous oxygen saturations could be maintained in the appropriate range, indicating flow was adequate. Since there was no elevation of the venous oxygen saturation and no evidence of air entering the pulmonary artery from the open left heart, retrograde flow from the left side of the heart through the lungs and into the pulmonary artery was discounted.

Discussion

Left thoracotomy with pulmonary artery to descending thoracic aorta or femoral artery bypass can be used as an alternate approach to vascular access for CPB. This approach should be considered when there is an increased risk of a median sternotomy incision and the operation under consideration will be performed on the left side of the heart including coronary artery bypass grafting. This approach to vascular access has also been used successfully to manage complicated descending thoracic aortic aneurysm repairs. However, when used in this circumstance, cardiac function is maintained allowing the right ventricle to counteract, providing flow to the pulmonary artery.

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