On-Pump Beating Heart Extraanatomical Ascending-Descending Aortic Bypass Using a Beating Heart Positioner in an Adult with Aortic Coarctation

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The prognosis of uncorrected aortic coarctation is poor due to development of heart failure. We performed an on-pump beating heart extraanatomical ascending-descending aortic bypass using a beating heart positioner in an adult with coarctation complicated by severe left ventricular hypertrophy. A 51-year-old woman was referred with severe hypertension. Computed tomography demonstrated severe distal aortic arch narrowing. Coarctation of the aorta was diagnosed. A posterior pericardial beating heart extraanatomical bypass via median sternotomy was performed from the ascending to descending aorta using a heart positioner. Her postoperative course was uneventful and blood pressure was normal on a low-dose beta-blocker.

Keywords: aortic coarctation, extraanatomical ascending-descending aortic bypass, on-pump beating heart surgery

Introduction
Coarctation of the aorta accounts for almost 5% of congenital heart disease. Untreated coarctation has a poor prognosis due to the eventual development of cardiac complications such as heart failure, aortic dissection, coronary artery disease, and cerebrovascular disease. Surgical management of coarctation in adults can be difficult in light of aneurysmal changes or calcification of the lesion and carries a risk of massive hemorrhage from enlarged collateral arteries. Extraanatomical bypass from the posterior pericardial approach via median sternotomy is a useful surgical option for adult patients. Here, we report an adult patient with coarctation of the aorta in whom on-pump beating heart extraanatomical ascending-descending aortic bypass was performed using a beating heart positioner.

Case Report
A 51-year-old woman presented to our center with a heart murmur and hypertension that was uncontrolled by high doses of oral antihypertensive agents. On examination, her blood pressure was 185/100 mmHg in the upper limb and 131/71 mmHg in the lower limb (ankle/brachial index: 0.7). There was a grade 3/6 systolic murmur in the left auscultatory triangle. An electrocardiogram showed left ventricular hypertrophy (LVH) with strain-type ST-segment depression in leads V5 and V6. Transthoracic echocardiography revealed significant LVH, mild impairment of left ventricular contraction, and a left ventricular ejection fraction of 0.50. She had a normal tricuspid aortic valve and no other congenital cardiac abnormalities, such as a ventricular septal defect or patent ductus arteriosus. Three-dimensional computed tomography (3D-CT) revealed severe coarctation of the aorta at the level of the origin of the left subclavian artery and moderate hypoplasia of the aortic arch (aortic arch diameter 17 mm) (Fig. 1). Aortography confirmed severe coarctation with a pressure gradient of 60 mm Hg, while coronary angiography showed that she had no coronary artery disease. Thus, the diagnosis was coarctation of the aorta associated with severe hypertension, and elective surgical management was planned. Fortunately, our patient had no large aneurysms surrounding the coarctation and only mild dilatation of the subclavian arteries (19–24 mm). Because her aortic arch was moderately hypoplastic, we felt that total arch replacement via left thoracotomy might be
necessary for her to undergo conventional graft replacement. However, we felt this approach too invasive and therefore chose extraanatomical bypass surgery via median sternotomy as a less-invasive option.

Full median sternotomy was performed. After systemic heparinization, normothermic cardiopulmonary bypass (CPB) was established via arterial cannulas in the ascending aorta and the left femoral artery along with bicaval cannulation. Left ventricular venting was not performed. The beating heart was retracted in the cranial direction using a heart positioner (Starfish®; Medtronic Inc., Minneapolis, MN, USA) (Fig. 2), and the posterior pericardium was opened longitudinally. The descending thoracic aorta was then exposed, and proximal and distal cross-clamps were placed. After a longitudinal incision of about 2 cm was made in the descending thoracic aorta, end-to-side anastomosis of a 14-mm Dacron tube graft (J graft®; Japan Lifeline, Co., Ltd., Tokyo, Japan) was performed using a 4-0 polypropylene running suture. The heart was then returned to the anatomical position, and the graft was guided through the pericardial cavity anterior to the inferior vena cava and on the right side of the right atrium to reach the ascending aorta. A side-biting clamp was placed on the ascending aorta, and a 2-cm longitudinal incision was made, after which graft anastomosis was performed in the same fashion as the distal anastomosis and the patient was weaned from CPB uneventfully. CPB time was 77 min, and the operating time was 143 min.

The patient’s postoperative course was uneventful. The pressure gradient between the upper and lower limbs resolved, and postoperative 3D-CT demonstrated good graft patency (Fig. 3). At present, the patient has no symptoms, and her blood pressure is normal on low-dose beta-blocker therapy.

Discussion

Coarctation of the aorta, which accounts for about 5% of congenital heart disease,1 is usually diagnosed in infancy or childhood, but diagnosis is sometimes delayed until adulthood in patients with uncomplicated coarctation and good collateral circulation. Patients with untreated
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coarctation of the aorta have a poor prognosis, with death eventually occurring due to cardiac complications such as congestive heart failure, aortic dissection or rupture, infective endocarditis, coronary artery disease, and cerebral hemorrhage.\(^6\) In addition, symptoms such as severe pulsatile headache and intermittent claudication can interfere with daily living. Therefore, surgical management should be considered before serious complications associated with coarctation of the aorta occur. A number of surgical techniques are available for dealing with coarctation of the aorta. Anatomical repair is commonly used, involving methods such as resection and direct end-to-end anastomosis, patch angioplasty, subclavian flap, and graft interposition.\(^3\) In addition, extraanatomical bypass and catheter intervention can be performed. However, anatomical repair via left thoracotomy can be difficult in some adult patients due to dense adhesions or calcification around the coarctation, difficulty in mobilizing the aortic arch, and bleeding from large collateral vessels with aneurysmal dilatation.\(^4\) Complications such as recurrent laryngeal nerve palsy, phrenic nerve injury, chylothorax, and spinal cord ischemia may also occur. Rokkas et al. reported on performing anatomical surgical resection of the diseased segment and replacement in adult coarctation patients using hypothermic CPB and circulatory arrest.\(^5\) Their results were striking, but, in general, this approach has been associated with high morbidity. In our case, if anatomical surgical repair had been performed, total arch replacement via left thoracotomy might have been necessary because her aortic arch was moderately hypoplastic; as such, the surgery would have had to be very extensive. Said et al. suggested that extraanatomical bypass might be a safer alternative to anatomical surgery for complex coarctation including arch stenosis, calcification, or recurrent coarctation.\(^6\) We therefore felt that extraanatomical bypass would be less invasive and a useful, safe option to avoid complications associated with anatomical repair.

Vijayanagar et al. described a novel method of extraanatomical ascending-descending aortic bypass using a posterior pericardial approach via median sternotomy,\(^7\) and several modifications of their method have been reported subsequently. This procedure is particularly useful for adult patients, and good results have been reported.\(^8\) However, several issues with this approach have been reported, such as postoperative prolonged mediastinal drainage following mediastinitis and aortoesophageal fistulas. The possibility of frictional wear between the graft and the moving heart is another concern. Further, future cardiac surgery, such as a mitral valve or tricuspid valve procedure, may be difficult due to the graft being positioned on the right side of the heart.

A heart positioner is employed to expose an adequate surgical field and to preserve stable hemodynamics in off-pump coronary artery bypass grafting. Athanasiou et al. reported the utility of this device in a number of surgeries, including pericardiectomy, dissection of adhesions during redo surgery, repair of trauma to the inferior or posterior left ventricular wall, and epicardial microwave ablation.\(^9\) These authors also demonstrated its use in off-pump extraanatomical bypass operations for recurrent coarctation. Aris et al. similarly reported a successful bypass from the ascending to descending aorta without cardiac arrest using a heart-lifting device.\(^9\) The beating heart positioner can assist with approaching the descending thoracic aorta through the posterior pericardium for distal anastomosis of the graft without requiring cardiac arrest. In selected cases, off-pump ascending-descending aortic bypass can also be performed using this device. In our case, we chose to totally clamp the descending thoracic aorta for the distal anastomosis because the patient’s descending thoracic aorta was very narrow (15 mm), and we felt that cardiopulmonary bypass was necessary to avoid spinal cord and visceral organ ischemia. Said et al. reported 80 consecutive ascending-descending posterior pericardial aortic bypass procedures via median sternotomy. Only two patients underwent off-pump ascending-descending aortic bypass, and one of these patients suffered from transient paraparesis. They reported that use of CPB allowed maintenance of adequate perfusion pressure and hemodynamic stability during graft anastomoses.

While cardiac arrest by injection of cardioplegic solution is safely performed in conventional cardiac surgeries, the resulting protection of hypertrophic, as opposed to normal, myocardium might be inadequate.\(^10\) Avoiding cardioplegia is important in adult coarctation patients, given their tendency to suffer LVH or hypertensive heart failure due to the long duration of severe hypertension. In the present patient, even though preoperative echocardiography detected severe LVH (15-mm-thick interventricular septum and posterior wall), intraoperative weaning from CPB was uneventful, requiring no inotropic drugs, and postoperative left ventricular function was preserved.

**Conclusion**

We performed on-pump beating heart extraanatomical ascending-descending aortic bypass using a beating heart positioner in an adult patient with coarctation of the aorta complicated by severe LVH. By employing a beating heart positioner that was designed for off-pump coronary artery bypass grafting, excellent exposure of the surgical field for distal anastomosis was achieved without cardiac arrest.

**Disclosure Statement**

The authors have no conflicts of interest to disclose in relation to this study.
Author Contributions

Study conception: TD
Data collection: TD, TG
Analysis: TD, TG
Writing: TD
Clinical review and revision: all authors
Final approval of the article: all authors
Accountability for all aspects of the work: all authors

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