Four different strategies for repair of aortic coarctation accompanied by cardiac lesions

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Abstract

OBJECTIVES: Coarctation accompanied by cardiac lesions is a complex clinical situation due to the presence of two different pathologies that necessitate surgical treatment. An individual strategy, according to the severity of the disease, is important to reduce perioperative mortality and morbidity.

METHODS: We report here on 25 patients with coarctation accompanied by cardiac lesions who were treated by various surgical approaches. Coarctation and associated disease were treated in 14 patients in a single stage by an ascending-to-descending bypass \((n = 11)\) or by a hybrid procedure \((n = 3)\). The remaining 11 patients underwent a two-stage operation for their treatment. Six of these 11 patients who had coronary artery disease or signs of congestive heart failure were first operated for their cardiac disease, whereas in the remaining five patients, who did not have any congestive signs, coarctation repair was performed first.

RESULTS: All the patients were male, between the ages of 20 and 24 years, except for one 45-year-old woman. The mean cross-clamp times, cardiopulmonary bypass times and operation times were 52 ± 14.5, 102.3 ± 28.5 and 174 ± 24.8 min in the extra-anatomical bypass group; 29.8 ± 11.7, 55.5 ± 17.6 and 116 ± 22 min in the two-stage groups and 49 ± 19.8, 63 ± 18.7 and 159 ± 21.3 min in the hybrid patients, respectively. One patient who underwent extra-anatomical bypass died on the 14th postoperative day. There were no events during the follow-up period for the other patients. Also, there were no gradients between the extremities and no graft-related complications.

CONCLUSIONS: As a consequence of the progress in the development of endovascular techniques, hybrid treatment is becoming a more popular option for the treatment of coarctation accompanied by cardiac diseases. Two-stage procedures and extra-anatomical bypass might be alternative techniques if endovascular procedures are contraindicated or failing.

Keywords: Coarctation · Endovascular procedures · Aortic aneurysm

INTRODUCTION

Aortic coarctation accompanied by cardiac lesions is a major clinical challenge because the pathology exists in two separate anatomical locations. To date, there is no consensus about how to approach such cases. It has been suggested in some reports that coarctation should be treated first, whereas other studies report that cardiac lesions should be treated prior to coarctation repair \([1–4]\). Perioperative morbidity and mortality risks are higher in the two-staged repair techniques because the patients undergo two separate surgical procedures. Also, two separate skin incisions could be a cause of concern for patients in the long term.

Single-stage techniques with a large incision are not commonly preferred due to the difficulty in exposure and in the control of unexpected bleeding \([5]\). Extra-anatomical bypass techniques should be performed as an alternative strategy, considering the advantages of treating two pathologies in a single stage and thus lowering perioperative risks \([6]\). In recent years, as a consequence of new developments in endovascular techniques, stent or stent graft deployment has become an alternative method for treatment of aortic coarctation \([7, 8]\). Especially in the presence of associated pathology, endovascular interventions allow repair of both lesions in the same surgical session. In this study, we assess the surgical procedures carried out on 25 patients who had aortic coarctation accompanied by cardiac lesions.

MATERIALS AND METHODS

We carried out a retrospective analysis of the patients who had been operated for aortic coarctation with associated cardiac pathologies between January 1998 and December 2012. We included aortic coarctation patients who had accompanying cardiac lesions. We evaluated demographic and clinical information, including the surgical techniques and outcomes, by reviewing medical records. Surgical strategy was determined individually based on the severity of the patient’s diseases and the surgical options during the case discussion session (Fig. 1, Table 1).
There were 117 patients, of whom 25 had coexisting cardiac pathologies, treated surgically due to coarctation between January 1998 and December 2012. The average age was 22.4 ± 4.8 years. There was only one 45-year-old woman, who had coexisting coronary artery disease. The remaining 24 patients were all male, between 20 and 24 years old. None of the patients had additional cardiovascular risk factors, except the woman patient, who had hyperlipidaemia.

Ascending-to-descending aortic bypass provides a single-stage repair of the coarctation and cardiac lesion. This approach is especially preferred for certain patients who have accompanying aortic aneurysm, to decrease the perioperative and postoperative complications. On the contrary, a two-stage repair is preferable for anatomical correction of the coarctation; however, it duplicates the anaesthetic and operational procedures. A hybrid procedure is another option for repair of the aortic coarctation and associated cardiac lesion.

We performed an ascending-to-descending bypass, a two-stage repair and hybrid procedures on 11, 11 and 3 patients, respectively (Table 2). The hybrid technique became available after 2007, when we started to perform endovascular procedures once the hybrid operating theatre was completed. We performed a single-stage repair with ascending-to-descending aortic bypass in 11 patients who had aortic coarctation with accompanying ascending aortic aneurysm or valve disease. Five of them underwent root replacement with the Bentall procedure. The remaining six patients underwent supracoronal tube graft replacement to the ascending aorta combined with aortic valve repair or aortic/mitral valve replacement (Table 2).

Arterial cannulation was maintained by aortic and femoral cannulation in six patients. In the next five patients, perfusion was maintained by the ascending aorta and the graft, which was anastomosed to the descending aorta. The size of the graft was determined by the diameter of the descending aorta at the diaphragmatic level [9, 10], which was 16, 18, 20, 22 and 24 mm in one, two, three, three and two patients, respectively. The graft was placed retrocavally in seven patients, whereas it was placed antecavally in four patients (Figs 2 and 3). In the ascending-to-descending bypass operation, the route of the graft was determined during surgery based on the surgeon’s decision. We decided to route the graft antecavally due to better configuration and bleeding control of the distal anastomotic site, because using the retrocaval approach it was difficult to control bleeding in first seven patients.

We performed a two-stage operation in 11 cases. In five patients, who did not have symptoms of congestive heart failure, the coarctation was operated first to decrease afterload. Two or three months after the coarctation surgery, coexisting pathologies (three ventricular septal defects, one atrial septal defect and one aortic insufficiency) were repaired with conventional surgery.

Patients who had symptoms or findings of congestive heart failure (volume overload on echocardiogram) or coronary artery disease underwent surgical repair of their cardiac disease in the first stage. Three aortic valve replacements (AVRs), one mitral valve replacement (MVR), one ventricular septal defect (VSD) repair and one coronary artery bypass grafting (CABG) operation were performed in the first step. Femoral cannulation was used in three of these patients. To prevent complications due to cannulation of

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**Table 1:** Advantages and disadvantages of the surgical options in the treatment of aortic coarctation accompanied by cardiac pathologies

<table>
<thead>
<tr>
<th>Procedure</th>
<th>Advantages</th>
<th>Disadvantages</th>
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<tbody>
<tr>
<td>Single-stage procedure: extra-anatomical bypass</td>
<td>Single anaesthetic procedure Easy to perform Anatomical correction Relieves proximal hypertension Safe aortic cannulation</td>
<td>Extra-anatomical nature Not suitable before adulthood Increases risk of bleeding Two anaesthetic procedures Two skin incisions Cosmetic dissatisfaction</td>
</tr>
<tr>
<td>Two-stage procedure: coarctation repair at first step</td>
<td>Anatomical correction Enables redistribution of myocardial and coronary flow Avoids ischaemia of left ventricle caused by sudden decrease of afterload</td>
<td>Two anaesthetic procedures Two skin incisions Cosmetic dissatisfaction Difficulty in control of bleeding Myocardial ischaemia in dilated ventricle Hypertensive complications</td>
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<tr>
<td>Two-stage procedure: cardiac lesion at first step</td>
<td>Anatomical correction</td>
<td>Two anaesthetic procedures Two skin incisions Cosmetic dissatisfaction Difficulty in control of bleeding Myocardial ischaemia in dilated ventricle Hypertensive complications</td>
</tr>
<tr>
<td>Hybrid procedure</td>
<td>Single anaesthetic procedure Simple technique</td>
<td>Insufficient long-term results</td>
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the femoral arteries with small diameters, we avoided femoral arterial cannulation. In these patients, we monitored femoral arterial blood pressure during the operation, and none of them required perfusion below the coarctation site. The coarctation repair was performed within the 2–3 months of the first stage. The coarctation was treated with an endovascular approach in three patients (Fig. 4) [11]. In these cases, MVR, mitral valve repair and VSD repair were performed using conventional techniques following NuMED CP stent graft (NuMED Inc., Heart Medical Europe BV, Best, Netherlands) implantation into the coarctation.

RESULTS

Mean cross-clamp times, cardiopulmonary bypass times and operation times were 52 ± 14.5, 102.3 ± 28.5 and 174 ± 24.8 min in the extra-anatomical bypass group, 29.8 ± 11.7, 55.5 ± 17.6 and 116 ± 22 min in the two-staged group (cardiac procedure) and 49 ± 19.8, 63 ± 18.7 and 159 ± 21.3 min in the hybrid group of patients, respectively. Mean mediastinal drainage in the extra-anatomical bypass group, two-staged patient group and hybrid patients was 670 ± 104, 488 ± 110 and 466 ± 104 ml, respectively. One patient who had undergone the ascending-to-descending bypass operation required re-exploration due to mediastinal bleeding. All patients were extubated uneventfully and discharged from the intensive care unit on the first postoperative day. There was no gradient between the upper and lower extremities in the follow-up period, and patients were discharged from the hospital in 9.1 ± 3.1 days (range 5–18 days).

All patients were followed for a mean of 17.3 ± 11.3 months (range 6–36 months). Sudden cardiac death occurred on the 14th postoperative day in one patient who had undergone ascending-to-descending bypass and AVR. The patient underwent urgent reoperation. A haemodynamically insignificant pericardial effusion was revealed at the reoperation. Although cardiopulmonary bypass was established, we were not able to disconnect the cardiopulmonary bypass, and the patient died due to a haemorrhagic diathesis complication from the cardiopulmonary bypass. There were no strokes or myocardial infarctions in the follow-up.
period. At follow-up examinations, echocardiography and computerized tomography revealed patency of the grafts. There were no gradients between the extremities and there were no late graft-related complications or reoperations. Blood pressure was controlled by angiotensin-converting enzyme inhibitors, β-blockers, a combination of these two drugs and without any treatments in 3, 7, 2 and 10 patients, respectively.

**DISCUSSION**

There are various strategies in the treatment of aortic coarctation associated with cardiac anomalies. Both single-stage and two-stage operations can be used [1–4]. Two-stage operations, in which the valvular lesion is treated in the first stage, enables myocardial and coronary flow redistribution [1]. Rufianchus et al. [2] reported that coronary perfusion is safer if the aortic valve surgery is performed at the first stage and the coarctation repair at the second stage during the same hospital stay. Mulay et al. [1] reported coarctation repair 6–12 weeks after valve surgery. Treatment of the coarctation in the second stage avoids ischaemia of the left ventricle due to a sudden decrease of afterload and related haemodynamic instability [1]. We repaired six cardiac pathologies with signs of congestive heart failure or coronary artery disease. We did not encounter any problems during the perioperative and hospitalization period in either the first or the second stage.

The increased afterload might be the cause of bleeding and haemodynamic instability in patients whose cardiac lesions are operated in the first stage [12]. Atrial fibrillation and ischaemia might occur in the dilated ventricle due to an increase in afterload after cross-clamping [13]. Also, ischaemia might occur in the distal segment of the coarctation as a consequence of low perfusion resulting in the development of low cardiac output syndrome [9]. In addition, the two-stage procedures, with the cardiac operation in the first step, can cause anticoagulation, renal perfusion and hypertensive complications [2]. Therefore, coarctation associated with valve disease but without signs of congestive heart failure might be repaired in the first stage [13]. We performed coarctation operations in first stage in five patients who had no signs of congestive failure without any complications.

Some surgeons prefer ascending aortic aneurysm repair, which is associated with coarctation, 1–5 weeks after the coarctation repair [3]. Repair of the coarctation in the first step eases blood pressure control and facilitates aortic cannulation in the second step by decreasing the aortic wall stress over the aortic aneurysm. Relieving the left ventricular outflow gradient decreases the risk of rupture and dissection of the aortic aneurysm during the repair of the aortic aneurysm [3]. If aneurysm repair is performed in the first stage, bleeding at the suture lines might occur in the aneurysmal aorta due to increased afterload caused by the coarctation. On the contrary, although treatment of the coarctation in first step decreases the afterload, the risk of rupture of the aortic aneurysm continues between the two procedures. Therefore, we prefer a single-stage procedure for treatment of a combination of ascending aortic aneurysm and coarctation.

Surgical repair of the two pathologies with combined thoracotomy and sternotomy incisions simultaneously in the single-stage procedure could increase postoperative pain and atelectasis. Also, there could be cosmetic problems related to two separate incisions. Coarctation and a cardiac lesion can be treated using a median sternotomy incision or by extending the median sternotomy incision through to the left infraclavicular level [14]. Respiratory problems due to lung compression, chylothorax, bleeding of fragile arteries, difficulty in the control of unexpected bleeding, laryngeal and phrenic nerve injuries are the potential risks of this approach [5, 12].

Repair of the aortic coarctation with an ascending-to-descending bypass, as first described by Vijayanagar et al. [6], is an alternative treatment approach for these combined pathologies. This technique is safer and easier, especially in patients with an ascending aortic aneurysm, coronary artery or valve disease associated with coarctation or recoarctation [5, 13, 15]. It is not appropriate before adulthood, because anastomotic dehiscence might occur during the growth period [5]. This technique was modified by Powell et al. [16], according to whom, passing the graft through the right side of the heart not only helps to avoid damage of left hilar vessels and phrenic nerve but also facilitates easy dissection during reoperation. Although perioperative morbidity is lower, bleeding caused re-exploration is approximately 10% in the extra-anatomical bypass [17]. This higher risk of bleeding has limited the popularity of this technique among surgeons. There are two different positions of the graft in relation to the inferior vena cava [17]. The antecaval approach avoids compression of the pulmonary veins and vena cava inferior, which could possibly happen in the retrocaval approach. In contrast, the retrocaval approach helps easy dissection during reoperation. Difficulty in the control of bleeding could arise with the retrocaval approach [10]. Kinking and stenosis might occur with long grafts. Compression of the right atrium and bleeding at the anastomotic site might be caused by short grafts [15]. We performed ascending-to-descending bypass operations in 11 patients. We routed the graft retrocavally in seven patients and antecavally in four. In our experience, we found that antecaval grafts are easier to configure and they promote good control of bleeding from the distal anastomotic site of the aorta.

In our opinion, they could make right atrial approach during reoperation easier.

Perfusion above and below the coarctation or single perfusion might maintain adequate blood flow to the whole body. Horai et al. [14] suggested perfusion above and below the coarctation in single-stage operations. In our previous cases, we maintained aortic and femoral cannulation, but more recently, we prefer perfusion below the coarctation only during extraanatomical bypass grafting. In other situations, we monitor the femoral arterial blood pressure during surgery via an arterial line, and there has not been any need for perfusion below the coarctation.

Repair of an isolated coarctation with a stent or stent graft has become popular with the development of endovascular techniques [13]. Endovascular repair of the coarctation is an alternative approach to surgery in patients older than 6 years old, with a lower risk of recurrence and aneurysm [8]. Development of balloon-in-balloon stent grafts, which can be redilated in the follow-up period, allows the use of endovascular techniques in children [7, 18, 19]. An endovascular approach might be performed in all coarctation cases except for isthmus hypoplasia, insufficient neck or failure to pass the coarctation with the guide wire. Old age has been reported as a risk factor for complications using the endovascular approach [20]. Intimal/transmural injury, dissection and aneurysm are the reported complications of balloon dilatation of coarctation [7, 21, 22]. Instead of stents, stent graft deployment avoids life-threatening complications of dissection or rupture [20, 22]. Coarctation associated with cardiac anomalies could be treated with either
a single-stage or a two-stage procedure using hybrid techniques. Aortic valve replacement 2 weeks after stent implantation to the coarctation has been reported [21]. This technique necessitates an additional general anaesthetic procedure and lengthens the hospital stay. We performed a hybrid technique in three patients with coarctation and accompanying cardiac lesions. After stent deployment, we operated on the cardiac pathology in the same procedure using conventional techniques without any complications. The mean operation time was longer than the cardiac procedure for the two-staged patients. However, two-stage techniques necessitate a coarctation operation with a second general anaesthetic procedure. The coarctation and associated lesions might be repaired in the same session with one general anaesthetic procedure, thereby reducing the length of hospital stay and cost.

The limitation of this study is its retrospective nature, which might cause a challenge to our algorithm. Aortic coarctation and accompanying lesions are very rare clinical cases. The decision concerning the surgical procedure to be employed is the most important step in treatment of these patients. In this article, we share our experience and our conclusions by evaluating these 25 cases.

Various strategies could be employed in the treatment of aortic coarctation accompanied by cardiac pathologies. The main step is to stratify the repair modality individually according to the severity of the diseases. In the surgical options, ascending-to-descending bypass should be performed for a coarctation accompanied by an ascending aortic aneurysm or critical aortic stenosis. In two-stage operations, the cardiac pathology should be operated in the first stage if congestive heart failure symptoms are observed. Currently, a single-stage operation with hybrid procedures might be a good option for most cases.

Conflict of interest: none declared.

REFERENCES


eComment. Ascending-descending aortic bypass in patients with complex aortic coarctation

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We read Ugur et al.’s study with interest [1]. Aortic coarctation surgery may be considered a well established procedure in paediatric congenital heart surgery. However, it becomes a complex and challenging procedure in adulthood, especially in the presence of accompanying anomalies. Until the last decade, ascending-descending aortic bypass with a posterior pericardial approach via a stent graft has been the gold standard for complex coarctation with excellent outcomes [2]. In the era of endovascular interventions, balloon dilatation and stenting have gradually become a reliable option for the management of isolated aortic coarctation [3]. Recently, a hybrid approach has become an alternative technique for treatment of complex cases with encouraging early results [4].

In our institution, we performed ascending-descending aortic bypass as a concomitant procedure in 11 adult patients (9 patients with aortic coarctation and 2 patients with type C interruption of aorta), who had accompanying cardiac diseases. All procedures were done with a median sternotomy and cardiopulmonary bypass in single stage. We performed simultaneous aortic valve replacement, coronary artery bypass grafting, ascending aorta replacement and the Bentall procedure in 4, 3, 2, and 2 patients, respectively. Ascending-descending aortic bypass was done with an anterior aortic approach. The Dacron graft was anastomosed to the lateral ascending aorta and extended toward the left ventricle lateral border. The posterior pericardium was opened and the descending aorta encircled. Descending aorta anastomosis was done with a side clamp. All patients survived surgery without any major adverse cardiac and neurologic events. One patient was reoperated because of infective