Clinical results of aortic arch replacement using a four branched prosthetic graft

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Recent advances in surgical techniques and assist procedures have improved surgical outcomes in the treatment of thoracic aortic aneurysms. However, the treatment of lesions involving the aortic arch is more complex, which often leads to unsatisfactory surgical outcomes and increased risk of cerebral complications. We report on the results of surgical and assist procedures used by our department for replacement of the aortic arch. In addition, we discuss potential problems associated with this procedure.

Materials and methods

Patients profile

Surgery was performed in 92 patients with thoracic aortic aneurysms by our department between January 1994 and December 2001. Aortic arch replacement was performed in 24 of these patients. This group included 16 males and 8 females, ranging in age from 42 to 81 years (mean, 59.4 years). There were 15 patients with acute Stanford type A dissections, 1 patient each with chronic Stanford type A and Stanford type B dissections, and 7 patients with true aortic arch aneurysms. Other preoperative complications were present in 73.3% of the acute dissection cases, including cardiac tamponade in 5 patients, myocardial ischemia in 2 patients, lower extremity ischemia in 2 patients, and aortic valve regurgitation in 1 patient. Among the true aortic arch aneurysm cases, 3 patients (42.9%) also had angina pectoris. Eleven (73.3%) of the patients with acute dissections required emergency surgery. Other sur-
surgical procedures performed included coronary artery bypass in 4 patients, suspension of the aortic valve in 1 patient, and a Bentall's procedure in 1 patient.

Operative techniques

Figure 1 depicts the method of cardiopulmonary bypass utilized by our department. Blood from the pump oxygenator was delivered \textit{via} the femoral or axillary artery and returned from the right atrium \textit{via} 1 or 2 tubes. Hypothermic circulatory arrest (HCA) was carried out at a body temperature of 20°C. Selective cerebral perfusion (SCP) was performed with bilateral cerebral perfusion of 400-600 mL/min and a perfusion pressure of about 50 mmHg. In patients requiring emergency surgery and those in whom preoperative cerebral angiography had confirmed anastomosis between the circle of Willis and the vertebrobasilar artery, perfusion of the left subclavian artery was not performed under HCA. Cardioplegia was carried out by antegrade or retrograde continuous cold blood cardioplegia (CCBC). In general, anesthesia was performed using a tube designed for separate left-right lung ventilation and the surgical approach was by median sternotomy. In patients with lesions extending to the distal arch and descending aorta, surgical approach was by median sternotomy and left anterolateral incision.

Aortic reconstruction was accomplished by open distal anastomosis on the distal side under HCA (Figure 2A). Stump formation in acute dissection cases was performed by placement of Teflon felt between the intima and adventitia of the dissection stump using gelatine resorcin formaldehyde glue (GRF glue). (Figure 2B). In chronic dissection cases, the intimal flap was resected in an arc-like fashion, with anastomosis in a double-barrel configuration (Figure 2C). The vascular graft was a 4-branched sealed graft (woven Dacron). The 3 branches of the arch were each reconstructed (Figures 2D, E). The order of anastomosis during arch replacement was the distal arch, left subclavian artery, and left common carotid artery. This was followed by reconstruction of the brachiocephalic artery. The final step was proximal anastomosis. After systemic circulation was re-established, the pump oxygenator was warmed and artificial cerebral and coronary circulations were discontinued.

Follow-up

The patients were followed up until November 2001 at outpatient clinic or were contacted by telephone or letter. The follow-up was 100% complete. The mean follow-up period was 2.3 years, and the longest period was 7.8 years.
Statistical methods

The continuous data in this study is expressed as means±SD. Survival was estimated by the Kaplan-Meier method.

Results

For all patients, mean total pump time was $204±53$ min, mean cardiac ischemic time was $136±41$ min, mean SCP time was $83±14$ min, and mean circulatory arrest time was $48±10$ min. In patients requiring 4 vessel CABG or Bentall's procedure, aortic cross-clamping time exceeded 200 min, but no problems were experienced in patients weaning from cardiopulmonary bypass. During the immediate postoperative period, 3 patients experienced bleeding from vascular anastomosis sites. Thoracotomy was again performed in these patients to control bleeding. Two patients in whom surgery was performed by median sternotomy and left anterolateral incision developed problems with postoperative sputum production. These patients required long-term respiratory management. In addition, 2 patients experienced wound infection. In 1 of these patients, omental packing was performed 2 weeks postoperatively and provided satisfactory results. The other patient experienced vascular graft infection. Surgery was again performed, but the patient developed sepsis and died. Six patients (25%) died while in hospital. Among the cases of acute dissection requiring emergency surgery, there were 3 patients in whom pump blood flow delivered via the femoral artery caused dilation of the false lumen, leading to abdominal visceral ischemia, multiple organ failure (MOF), and death. None of these patients had any problems with the cardiopulmonary system during surgery, but postoperative intestinal necrosis developed.

Two of these patients experienced cerebral infarcts, and both had been diagnosed with true aortic arch aneurysm. The jet flow from the pump blood probably caused circulation of aneurysmal debris, leading to development of cerebral embolism. One patient who died experienced myonephropathic metabolic syndrome (MNMS) due to lower extremity ischemia. This patient required emergency surgery and also had coexisting myocardial ischemia. CABG was initially performed, but there was postoperative progression of lower extremity ischemia. Long-term postoperative monitoring ranged from 4 months to 7 years, with a mean follow-up period of 2.3 years (Figure 3). The 5-year survival rate was 76% for the entire group and 86% for the low risk group (excluding the 6 patients who died while hospitalized). This indicates a relatively good long-term prognosis in patients whose preoperative condition is stable.

Discussion and conclusions

Improvements in surgical techniques and assist procedures are key to improved surgical outcomes in the treatment of thoracic aortic aneurysms. Assist procedures include selective cerebral perfusion (SCP), hypothermic circulatory arrest (HCA), and continuous cold blood cardioplegia (CCBG). SCP was first used in Japan by Asano. Maintaining high cerebral perfusion flow under mild hypothermia of 30°C was regarded by some as satisfactory, but a high incidence of complications was observed. Lower perfusion flow at about 40% cerebral perfusion of room temperature under deep hypothermia at 20°C is now regarded as more effective. This is associated with a lower incidence of cerebral complications and is useful in relaxing time limitations. However, 1 drawback of SCP is the need for a perfusion cannula and possible interference with the surgical field. Retrograde cerebral perfusion is relatively easy to perform and does not interfere with the surgical field. However, in patients with venous valves in the brain, adequate perfusion may be difficult to achieve, limiting perfusion time. SCP was therefore selected to avoid limi-
tations on cerebral perfusion time. SCP has become a reliable method for brain protection during reconstruction of the transverse aortic arch. However, arterial cannulation technique for the branches of the aortic arch varies among cases, and the necessity of perfusion for the left subclavian artery is controversial. The reason for not performing perfusion via the left subclavian artery was because the temperature of the antegrade cerebral perfusate was 30°C during SCP and deep hypothermic cardiopulmonary bypass was performed until reconstruction to the left subclavian artery. Cerebral angiography was performed in chronic cases, and perfusion was not carried out in any patient with evidence of communication between the circle of Willis and the vertebrobasilar artery. HCA is relatively easy to perform and provides a bloodless field, but limitations to circulatory arrest time make this procedure unsuitable for some patients. In cases where circulatory arrest exceeds 60 minutes, we temporarily use antegrade or retrograde perfusion of 600–1000 mL of pump blood flow. In our department, cardioplegia is generally performed by administration of Jynge solution 2 mL/kg and priming GIK solution 20 mL/kg, followed by antegrade or retrograde CCB by a pump oxygenator. Complications associated with delivery of blood from the femoral artery included dilatation of the false lumen and abdominal visceral ischemia in 3 patients. Particular attention must be paid to the site of blood delivery in patients undergoing emergency surgery. In addition, the jet flow from pumped blood may cause circulation of aneurysmal debris and subsequent development of a cerebral embolism in patients with true aortic arch dissections. Blood flow during cardiopulmonary bypass must therefore be carefully regulated in these types of patients. The surgical procedure in patients with acute dissection was open distal anastomosis on the distal side under HCA. The false lumen was closed by placing Teflon felt between the intima and adventitia and using a biovacular adhesive (GRF glue) to reinforce the stump. In chronic dissection cases, the intimal flap was resected in an arc-like fashion, with anastomosis in a double-barrel configuration that included both true and false lumens. Dilatation of the false lumen and rupture of the false lumen wall have been reported with this method in patients with acute dissection. However, in our chronic dissection cases, re-entry was achieved from the distal side. We consider this to be an appropriate procedure when thickening of the false lumen wall is present. For reconstruction of the arch branches, completion of the open distal anastomosis was followed immediately by re-establishing systemic circulation via a branch of the prosthetic graft for cardiopulmonary bypass. Rewarming was initiated and proximal anastomoses of the subclavian artery, left common carotid artery, and right brachiocephalic artery with the aorta were performed by separated graft technique. It has been recognized that atherosclerosis of the ascending and arch aorta is a major cause of stroke after aortic surgery. Therefore, our separated graft technique about the extent of aortic replacement is that all the potential sources of cerebral embolism must be radically removed, and that is why we also replace the arch replacement. We have extensively used the separated graft technique by using the aortic arch branched graft for atherosclerotic arch aneurysm. This technique has several advantages when compared with inclusion and en bloc technique, in which the arch vessels are anastomosed to the side hole of the arch graft in an island fashion. The use of a separated graft technique automatically excludes the atherosclerotic lesion at the origins of the arch vessels and also allows us to easily control bleeding from the posterior wall of the anastomosis site. These can reduce the incidence of postoperative complications. The separated graft technique is frequently utilized in Japan, and we have achieved excellent results using this procedure. The prosthetic graft used was a 4-branched sealed graft. This is a woven Dacron graft with a diameter of 22 to 30 mm and branches for the brachiocephalic artery (10 mm), left common carotid artery (8 mm), left subclavian artery (8 mm), and pump perfusion (10 mm). This method is also effective in reducing the time of surgery when adequate personnel may not be available. Prolonged total pump times can adversely affect respiratory function and influence surgical outcomes. In our patients, mean total pump time was 204 minutes. Postoperative complications included bleeding, respiratory impairment, and wound infection. Six patients (25%) were in shock before surgery and required emergency operation. These patients experienced complications associated with cardiopulmonary bypass and later died. Preoperative evaluation of aortic dissection in each patient is essential in selecting the most suitable means of arterial perfusion for cardiopulmonary bypass. Our long-term results demonstrate a 5-year survival rate of 86% (excluding high-risk patients). We have described a
useful surgical procedure for treatment of aortic arch aneurysms utilizing replacement with a 4-branched prosthetic graft and open distal anastomosis under SCP and HCA. Problems that still must be resolved include interference with the surgical field by SCP and complications associated with cardiopulmonary bypass.

References


