■ 症　　例　　日血外会誌 14：729–732，2005

Beating-heart Aortic Arch Replacement in a Patient with Severely Impaired Ventricular Function

Hirokazu Murayama, Souichi Asano, Hiroyuki Kito,
Atsushi Tamura and Katsuhiko Tatsuno

Abstract: A 69-year-old man with a previous history of extensive anteroseptal infarction developed hoarseness and an aortic arch aneurysm with a maximum diameter of 80 mm was found. The patient had been frequently admitted for heart failure, and echocardiography showed that the left ventricular ejection fraction had decreased to 21.5%. We performed aortic arch replacement with the patient's heart beating using continuous coronary perfusion by retroperfusion via the coronary sinus and antegrade perfusion via the aortic root. The postoperative hemodynamics were stable and the patient made a good recovery without any major complication. Beating-heart aortic arch replacement may be a promising method in a patient with severely impaired ventricular function who is at a risk of deterioration after cardioplegic arrest. (Jpn. J. Vasc. Surg., 14: 729–732, 2005)

Key words: Aortic arch replacement, Beating heart surgery, Impaired ventricular function

Introduction

Conventional total arch replacement usually requires cardioplegic arrest during aortic anastomosis. However, the risk of surgery is high for patients with severely impaired ventricular function, because postoperative aggravation of cardiac function after reperfusion cannot be avoided, even when cardioplegic methods such as warm cardioplegia are used. Here, we present a novel strategy to approach this problem, using a beating-heart method in a patient requiring total arch replacement, and in which the postoperative course was smooth and postoperative deterioration of cardiac function did not occur.

Case Report

A 69-year-old man with a history of extensive anterior myocardial infarction was referred to our cardiology clinic complaining of hoarseness. He had been hospitalized three times for congestive heart failure and ventricular arrhythmia since percutaneous coronary intervention was performed for a left anterior descending (LAD) lesion at the age of 67. Paralysis of the recurrent laryngeal nerve was diagnosed. A chest X-ray showed a prominent left aortic arch shadow, and computed tomography demonstrated a true aortic arch aneurysm of 80 mm with a mural thrombus (**Fig. 1**). Echocardiography demonstrated global hypokinesis with a left ventricular diastolic dimension of 76.5 mm. The left ventricular ejection fraction (LVEF) was found to be 21.5%. Mild mitral and tricuspid valve regurgitation was diagnosed by Doppler echocardiography. Coronary angiography revealed mild stenosis in the right coronary arteries (#2) and the stented site of the LAD lesion (#6). Left ventriculography showed diffuse impairment of the wall kinetics. The left ventricular end-diastolic volume index was 118 ml/m^2. Despite severely impaired ventricular function, surgery was indicated because it was judged that the aneurysmal dilatation of 80 mm had a high risk of rupture.

After median sternotomy, the right axillar and femoral artery were cannulated and venous outflow was achieved by

Department of Cardiovascular Surgery, Chiba Cardiovascular Center
(Tel: 0436-88-3111)
575 Tsurumai, Ichihara, Chiba, 290-0512 Japan
Received: April 4, 2005
Revision accepted: August 29, 2005

routine bicaval cannulation. After cardiopulmonary bypass was started, the right atrium was opened and a retrograde cannula was inserted through the coronary sinus and secured with a purse-string suture around the ostium to prevent leakage flow. The aorta was cross clamped and retrograde oxygenated blood (34˚C) was infused through the coronary sinus cannula at a rate of approximately 250 ml/min, giving an average coronary sinus pressure of 50 mmHg. After confirming normal cardiac contraction macroscopically and the absence of electrocardiogram (ECG) change, the ascending aorta was transected and proximal anastomosis with a 30-mm woven graft was performed (**Fig. 2A**). Upon completion of anastomosis, coronary perfusion was changed from retrograde to antegrade (30˚C) through a cannula at the ascending graft, at a rate of 400 ml/min. During systemic cooling, reconstruction of the brachiocephalic trunk was performed with partial cerebral perfusion through the right axillar cannula. The aortic arch was entered when the bladder temperature decreased to 26˚C. The left common carotid artery and the left subclavian artery were cannulated directly and selective cerebral perfusion was established with a total flow rate of 500 ml/min. The distal arch was transected and peripheral aortic anastomosis to the distal graft was performed with continuous sutures. During anastomosis, abdominal organs were perfused through the femoral cannula with an occlusion balloon placed at the descending aorta (**Fig. 2B**). Upon completion of distal anastomosis, the distal graft and proximal graft were connected with continuous sutures. After the heart and the graft were deaired, antegrade systemic perfusion was started through the branch of the graft and ordinary coronary circulation was started. The rest of the arch vessels were reconstructed in the usual manner. Because the heart was kept beating during the whole procedure, the patient was easily weaned from cardiopulmonary bypass with low dose administration of an inotrope. The total cardiopulmonary bypass time was 388 minutes, which included a selective cerebral perfusion time of 167 minutes and a circulatory arrest time of 24 minutes for open distal anastomosis. The postoperative course was uneventful. During the early period in the intensive care unit, the cardiac index was kept between 2.5–3.4 L/min/m^2. The patient was extubated 10 hours after the operation, and he moved to the normal ward on the 3rd postoperative day. He made a smooth recovery, except for an episode of paroxysmal atrial fibrillation, which was treated with drugs. Postoperative echocardiography showed an LVEDd (left ventricular end diastolic diameter) of 60.4 mm and an LVEF of 24%, suggesting no aggravation after surgery. The patient was discharged to home on the 29th postoperative day.

Fig. 1 Computed tomography scan showing an aortic arch aneurysm with mural thrombus, 80 mm in diameter.

Discussion

Establishment of brain-protective methods has resulted in stable outcomes following aortic arch replacement, with a hospital mortality of 7% in Japan.[1)] With these improved outcomes, the numbers of elderly and high-risk patients with complications requiring aortic surgery have increased. Although associated coronary arterial lesions are not rare in a patient with aortic arch aneurysm, postoperative improvement of ventricular function by coronary arterial bypass cannot be expected in patients with myocardial infarction-induced ventricular dysfunction, such as in the current patient. Thus, with ordinary aortic surgery performed under cardioplegic cardiac arrest, it is difficult to avoid postoperative aggravation of poor ventricular function. In order to reduce postoperative aggravation, some procedure such as the proximal first technique,[2)] have been used to shorten the duration of cardiac arrest so far. The fact that warm heart surgery with the use of continuous warm blood cardioplegia yields good myocaridial protection is well known. However, even with this method, myocardial edema as well as ischemia-reperfusion injury, which is intrinsic to an arrested heart, cannot be avoided.

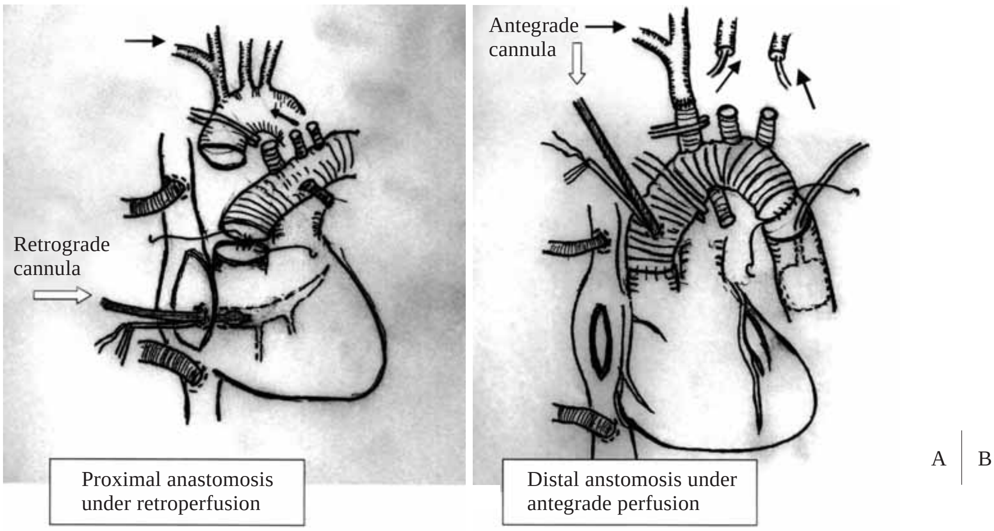

Fig. 2 A: Proximal anastomosis under cross clamping ascending aorta followed by retrograde coronary perfusion.
B: Distal anastomosis with antegrade coronary perfusion via cannula placed at the arch graft. The selective cerebral perfusion is restored during this procedure under moderate hypothermia, with the bladder temperature at 26˚C.

Adverse effects of myocardial contraction after cardiac arrest may easily develop, especially in patients with severely impaired ventricular function. Recently, beating-heart surgery for valvular disease using antegrade or retrograde coronary perfusion of oxygenated blood at normal temperature has been reported for patients with ventricular dysfunction or with other complications.[3-5] This method allows continuation of heart beating with no volume load. Myocardial edema as well as ischemic-reperfusion injury induced by cardiac arrest can be avoided by this method, offering better cardiac function after surgery. This beating-heart technique is applicable to surgery of the aortic arch using retrograde coronary perfusion. In our approach, proximal anastomosis was performed under retrograde coronary perfusion (250–300 ml/min), and heart beating was maintained thereafter by antegrade coronary perfusion (400 ml/min) via a cannula inserted into the proximal graft. It is possible that the whole process is performed under retrograde perfusion, but we consider that the antegrade method provides more physiological and reliable coronary perfusion.

The most important concern in our method is maintenance of a sufficient myocardial blood flow. However, no objective monitoring method is available for determining optimum myocardial blood flow. The procedure should be carefully performed with measurement of the coronary perfusion flow and perfusion pressure, and attention should be paid to changes in the ECG and the macroscopic condition of the heart beats. In addition, consideration of the risk of coronary sinus injury due to an increase in perfusion pressure is necessary during retrograde coronary perfusion, and while heart beating is maintained by antegrade coronary perfusion under aortic crossclamp, removal of the left ventricular volume load by sufficient venting is also important.

Temperature management during surgery is also a concern. A warm temperature is necessary to maintain heart beating, but a low temperature is necessary for protection of the brain and organs of the whole body. Establishment of an optimum temperature to satisfy these two contradictory requirements is therefore necessary. Normally, coronary perfusion at ordinary physiological temperature is performed in beating-heart valvular surgery. However, in the current patient, we set the temperature of the blood for coronary perfusion at 30˚C to reduce the difference in temperature from that of the blood supplied by the systemic circulation. A decreased temperature (26˚C in our case) of the systemic circulation is particularly necessary for distal anastomosis of the aorta, because circulation is temporarily suspended. Acclimation of the heart muscle to a slightly lower temperature may inhibit arrhythmia, such as ventricular fibrillation, induced by cooling surrounding tissue of the heart. In addition, we arranged heat-insulating sheets around the heart to prevent heat conduction as much as possible. In fact, transient ventricular fibrillation occurred during cooling in the current patient and defibrillation was required, suggesting that accumulation of cases is necessary to investigate the optimum temperature management for maintenance of stable heart beating.

Normal coronary circulation by systemic antegrade perfusion via the graft was resumed after completion of the peripheral anastomosis, and subsequent reconstruction of the arch branches was performed by the usual procedure. Since heart beating was maintained, weaning from extracorporeal circulation was performed smoothly within a short time after completion of the procedure. Postoperative hemodynamic status was stable without adverse events related to intraoperative ischemia.

As for total arch replacement without cardiac arrest, many procedures were presented such as the report made by Kimoto et al.[6] in 1961. In their report, they performed successful total arch replacement using partial clamping of ascending aorta and temporary occulusion of arch branches under temporary bypass support. However, these methods are not used as a standard technique recently because of the complicated nature of the procedure, the reliability of brain protection and the risk of thromboembolism due to partial clamping. Instead of partial clamping, we use a selective cerebral perfusion procedure. Furthermore, it has an advantage to repair the proximal ascending aorta including the aortic root by keeping beating-heart with the retrograde coronary perfusion method as we described.

We believe that beating-heart aortic arch replacement might offer some benefit to patients with arch aneurysm accompanied by impaired ventricular function who cannot tolerate cardiac arrest-induced myocardial disorder. We intend to continue investigation of this approach in further patients to confirm this result.

References

1) Yada, I., Wada, H. and Fujita, H., Committee of Science: Thoracic and Cardiovascular Surgery in Japan during 2002. Annual Report by The Japanese Association for Thoracic Surgery. Jpn. J. Thorac. Cardiovasc. Surg., **52**: 491-499, 2002.
2) Tominaga, R., Kurisu, K., Ochiai, Y., et al.: Early proximal aortic reperfusion in total arch replacement. Jpn. J. Vasc. Surg., **11**: 511-516, 2002.
3) Gersak, B. and Sutlic, Z.: Aortic and mitral valve surgery on the beating heart is lowering cardiopulmonary bypass and aortic cross clamp time. Heart Surg. Forum, **5**: 182-186, 2002.
4) Kaplon, R. J., Pham, S. M. and Salerno, T. A.: Beating-heart valvular surgery: A possible alternative for patients with severely compromised ventricular function. J. Card. Surg., **17**: 170-172, 2002.
5) Masroor, S., Lombardi, P., Tehrani, H., et al.: Beating-heart valve surgery in patients with renal failure requiring hemodialysis. J. Heart Valve Dis., **13**: 302-306, 2004.
6) Kimoto, S., Wada, T., Suzuki, A., et al.: Surgical treatment of aneurysm of the aortic arch: Report of two operated cases with synthetic prostheses. Jpn. Heart J., **2**: 119-129, 1961.