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Whole-Body Perfusion under Moderate-Degree Hypothermia during Aortic Arch Repair

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ABSTRACT

Introduction. There continue to be some controversies concerning aortic arch reconstruction, especially the cerebral protection methods. We report our operative and postoperative outcomes for cases of aortic arch replacement using whole-body perfusion during aortic reconstruction under 28°C moderate hypothermia.

Materials and Methods. A total of 12 patients were operated on between March 2003 and November 2005. Two of the patients were female. The mean age of the patients was 53.5 ± 7.3 years (range, 42-65 years). We cannulated the right axillary artery for cerebral perfusion and the right femoral artery for body perfusion. Arch replacement was done under continuous antegrade cerebral perfusion through the right axillary artery and continuous body perfusion through the right femoral artery via intra-aortic occlusion of the proximal descending aorta with an intra-aortic occlusion catheter. Perioperative data and postoperative outcomes, blood urea nitrogen, serum creatinine, and alanin aminotransferase values were evaluated retrospectively in the patients.

Results. There was only 1 hospital mortality. There were no neurologic complications. Postoperative levels of blood urea nitrogen and creatinin did not show significant difference but the alanin aminotransferase levels were significantly higher in the postoperative period, which was within the normal ranges of cardiopulmonary bypass effect.

Discussion. Whole-body perfusion through the axillary and femoral arteries may provide more time for the surgeon and good cerebral and visceral protection, which are especially important for surgical teams in the learning curve.

INTRODUCTION

There have been major advances in aortic arch surgery; however, some issues remain controversial among surgeons. One of the most important is the cerebral protection method. Some techniques have been suggested such as antegrade cerebral perfusion (ACP), deep hypothermic circulatory arrest, and retrograde cerebral perfusion (RCP). However, which method is best for cerebral protection remains a dilemma. ACP became the preferred technique of cerebral protection in recent years as it was realized that the other techniques did not provide satisfactory cerebral protection yet had harmful effects of profound hypothermia [Boeckxstaens 1995; Westaby 1995; Coselli 1997; Ye 1997].

ACP through the right axillary artery has been proven to be a safe and effective method for cerebral protection in aortic surgery. It has become the preferred site for cannulation and is indicated in wider areas. On the other hand, ACP under moderate hypothermia was reported to poorly protect visceral organs such as the liver when compared with deep hypothermia [Svensson 2002]. To overcome this, ACP through the right axillary or brachial artery was offered as an alternative technique to descending aortic perfusion through the femoral artery with the aid of descending aortic occlusion [Novitzky 2002; Kucuker 2005]. In this study, we present our results of arch replacement under moderate-degree hypothermia and whole-body perfusion.

PATIENTS AND METHODS

Patients

The data of the patients who were operated on by the whole-body perfusion technique were retrospectively analyzed. A total of 12 patients were operated on between March 2003 and November 2005. Two of the patients were female. The mean age of the patients was 53.5 ± 7.3 years (range, 42-65 years). The preoperative coexisting pathologies were hypertension in 9 patients, diabetes in 2 patients, chronic obstructive pulmonary disease in 2 patients, coronary artery disease in 2 patients, and Marfan syndrome in 1 patient. The surgical indications were chronic type A aortic dissection in 5 patients, acute type A aortic dissection in 4 patients, and ascending and arch aorta aneurysm in 3 patients. Perioperative data and postoperative outcomes of the patients besides preoperative and postoperative fifth day values of blood urea nitrogen (BUN), serum creatinine, and alanin aminotransferase (ALT) levels were evaluated in the patients. Normal values of serum creatinin, BUN, and ALT ranged between 0.6 to 1.1 mg/dL, 7 to 25.7 mg/dL, and 5 to 45 U/L, respectively.

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Surgical Technique

The operations were performed under general anesthesia. Arterial lines were routinely placed on both radial arteries for pressure monitoring. Preoperative routine upper extremity arterial examination was done to every patient to avoid any malperfusion. The right axillary artery was cannulated for cerebral perfusion and the right femoral artery for the rest of the body perfusion. The axillary artery was exposed through an incision made inferior and parallel to the lateral two thirds of the clavicle. After heparin administration, an 8-mm Dacron vascular graft was anastomosed to the axillary artery in an end-to-side fashion with a continuous 6-0 polypropylene suture. After the anastomosis, the graft was cannulated with a 21 F cannula for arterial line. The right femoral artery was preferred for cannulation for body perfusion. It was also cannulated with a 21 F cannula. The cannulas of both arterial sites were connected to each other and to the head of the roller pump by a Y-connector. Venous cannulation was performed with a 2-stage right atrial cannula. A retrograde cardioplegia cannula was inserted to the coronary sinus. The brachiocephalic and left carotid arteries were prepared before cardiopulmonary bypass (CPB) was started. An 18 F vent cannula was inserted into the right superior pulmonary vein for venting the heart.

All operations were performed under moderate degree hypothermia with a nasopharyngeal temperature of 28°C. Both of the radial artery pressures were checked at the beginning of CPB for the presence of malperfusion. After cross clamping the ascending aorta, we accomplished cardiac arrest with antegrade infusion of isothermic hyperkalemic blood cardioplegia. Arrest was maintained by a continuous retrograde infusion of maintenance cardioplegia. Open distal anastomosis was done in all of the patients. Vascular clamps were placed on the proximal innominate and left carotid arteries and pump flow was decreased to 500 to 700 mL/min. The femoral line was clamped and the aorta was transected. An intra-aortic balloon occluder (Pruitt Aortic Occlusion Catheter; LeMaitre Vascular, St. Petersburg, FL, USA) was inserted into the proximal part of the descending aorta and the balloon was distended with saline. The femoral line clamp was removed and the balloon of the intra-aortic occluder was filled again until the descending aortic blood return ceased. The maximal flow rate was attained, and arch replacement was done under whole-body perfusion. After completion of the anastomosis, the balloon occluder was deflated. The graft was clamped after it was filled with blood. Arch branches were declamped and the femoral artery line was clamped. The body was perfused through the axillary artery thereafter. After the proximal aortic anastomosis, the clamp on the aortic graft was removed and the heart was reperfused. The femoral artery was repaired during this period. As the patient left CPB, the axillary artery graft was clamped, cut, and oversewn.

Statistical Analysis

Statistical analysis was done with a SPSS 10.0 statistical software program (SPSS, Chicago, IL, USA). Continuous variables were expressed as mean ± 1 standard deviation. Continuous variables of the biochemical values were compared by the Mann-Whitney U test. P less than .05 was considered to be statistically significant.

RESULTS

There was only 1 hospital mortality, which occurred on the sixth postoperative day due to respiratory complications. No neurologic deficit, neither transient nor permanent, was observed in the patients. Perioperative data of the patients are seen in Table 1.

The operative procedures were total arch replacement in all of the patients. In addition, ascending aortic replacement was peformed in 5 patients, Bentall procedure was applied in 3 patients, and coronary artery bypass was performed in 1 patient.

Postoperative levels of BUN and creatinin did not show a significant increase, but the ALT levels were significantly higher in the postoperative period (Table 2).

DISCUSSION

The cerebral protection methods in arch surgery have been well defined with their advantages and disadvantages in the recent reports. ACP gained popularity in the recent years with its sufficient postoperative outcomes. Svensson et al reported that the brain was incompletely perfused by the RCP method [Svensson 2001]. The incidence of temporary neurological dysfunction was reported to be significantly higher in patients with RCP than in those with ACP [Okita 2001]. Hagl et al concluded that the method of cerebral protection did not influence the occurrence of stroke, but ACP resulted in a significant reduction in the incidence of temporary neurological dysfunction [Hagl 2001]. Most of the series suggest ACP for patients who need longer cerebral protection because it can provide the luxury of time, allowing for appropriate repair of complicated arch aneurysms. However, ACP was thought to have the potential disadvantage of

Table 1. Operative and Postoperative Patient Data

	Minimum	Maximum	Mean	Standard Deviation
Cardiopulmonary bypass time, min	100	360	193.2	89.0
Myocardial ischemia time, min	67	255	117.5	55.3
Respiratory support time, h	12	96	35.7	25.3
Intensive care unit follow-up, d	2	12	3.7	2.7
Postoperative hospital follow-up, d	6	18	8.2	3.2
Postoperative hemorrhage, mL	500	3000	1200.0	690.2
Blood transfusion, 450-mL bag	1	9	3.4	2.2
Fresh frozen plasma transfusion, 250-mL bag	0	3	1.8	0.7

Table 2. Biochemical Measures*

	Preoperative	Postoperative	*P*
Blood urea nitrogen, mg/dL	27.0 ± 5.0	32.2 ± 7.4	.087
Creatinine, mg/dL	0.9 ± 0.2	1.1 ± 0.3	.098
Alanin aminotransferase, U/L	27.0 ± 6.5	33.7 ± 6.6	.032*

*Indicates statistical significance.

requiring manipulation of cerebral vessels, thereby risking dislodging atherosclerotic debris [Matalanis 2003].

Transverse aortic arch repair is a technically demanding and time-consuming operation. It may be more troublesome especially in acute type A dissection. For this reason, many surgeons have switched to selective ACP. Kucuker and associates reported a unilateral ACP technique via the right brachial artery in conjunction with moderate hypothermia under 26°C with excellent neurological outcomes [Kucuker 2005]. To show the effect of unilateral perfusion, neurocognitive functions of both the right and left hemisphere pre- and postoperatively on the first week and second month postoperatively were reported to be normal and the flow patterns of both the middle cerebral arteries before, during, and after low-flow antegrade selective cerebral perfusion with transcranial Doppler (TCD) measurements showed a reduction of blood flow at the left side after the onset of ACP [Ozatik 2004]. TCD also revealed that the blood flow never stopped and this reduced flow, as far as our neurological results were concerned, was satisfactory to maintain the metabolism of the left hemisphere [Karadeniz 2005]. Most of the studies are concentrated on cerebral perfusion; however, what the effect of moderate hypothermia on the visceral organs might be remains a problem. Novitzky and Kucuker offered additional femoral artery cannulation as an option for acute dissection cases with renal, visceral, or lower extremity malperfusion, especially when the surgeon expects a long arch repair time [Kucuker 2001; Novitzky 2005]. To prevent further ischemia during the selective antegrade perfusion period, distal perfusion can be provided with femoral artery cannulation following the insertion of an intra-aortic balloon occluder into the proximal descending aorta. Novitzky and associates reported a case of type A aortic dissection using the mentioned technique [Novitzky 2005]. Tagaki and associates used the technique under 25°C with an aortic balloon occlusion catheter with perfusion lumen for protection of the lower body during distal anastomosis in an aortic arch repair. Antegrade perfusion for the lower half of the body was recommended as a useful supportive technique to protect against ischemia or embolism of the abdominal organs [Takagi 2002]. Klodell and associates perfused the distal aorta at a bladder temperature of 18°C. They suggested that the technique allowed continuance of cerebral protection with the added benefit of maintaining antegrade flow to the distal aorta, spinal cord, viscera, and lower extremities [Klodell 2004]. Yet the distal aortic perfusion of the spinal cord, viscera, and lower extremities avoids the need for deep hypothermia [Takagi 2005]. We used similar perfusion techniques but with a nasopharyngeal temperature of 28°C. Our results suggest the safety of moderate hypothermia on cerebral and visceral perfusion. Moreover, ACP at physiologic pressures with systemic circulatory arrest at moderate hypothermia over 22°C was reported to provide superior cerebral protection by combining the protective effects of reduced metabolic demand secondary to moderate hypothermia while avoiding the negative cerebrovascular effects of deep hypothermia [Cook 2006]. However, there is not a prospective and randomized study about this and there may be some technical problems in this technique. In case of a severe calcification or ectasia, tight occlusion of the descending aorta may not be possible. The balloon of the aortic occluder should not be distally located in the descending aorta and should be optimally inflated to avoid damaging the aortic wall. This will make the intra-aortic balloon occluder stay in the right position and not dislocate during the procedure; besides, the spinal cord and the visceral perfusion will not be disturbed. There may be proximal migration of the occluding catheter. The catheter may interfere with vision and suture placement. We did not meet such problems in our applications. Furthermore, we did not meet any backbleeding through the false lumen of the aorta in aortic dissection.

An additional cannulation site can be utilized, as in our cases, but the femoral artery is a potential site for further morbidity. This may be overcome via a perfusion balloon cannula inserted from above. In atheromatous aortic disease, this might avoid retrograde perfusion of the descending aorta via the femoral artery and might further avoid atheroembolism.

Shimazaki et al reported 2.5% mild renal dysfunction versus 2.5% liver dysfunction in a mean of 50 minutes cessation of distal aortic perfusion under 28°C [Shimazaki 2004]. In Kucuker's study, postoperative renal and hepatic function tests showed significant difference when compared with the preoperative values, but these were reported to be within normal limits for routine cardiac operations [Kucuker 2005]. They advised caution when using this technique for longer durations. Our study did show excellent visceral outcomes concerning the postoperative renal functions [Weinstein 1989]. The ALT values were significantly higher in the postoperative period but were also in the normal limits [Autschbach 1996]. This may be due to distal aortic perfusion, but the study population is limited and such a conclusion necessitates a randomized trial.

Consequently, the relatively shorter CPB times, myocardial ischemia times, and need for transfusion may also suggest the importance of avoiding deep hypothermia. Our satisfactory results may suggest that whole-body perfusion through axillary and femoral artery combination may provide more time for the surgeon and better protection concerning the brain and visceral organs, and this is especially important for surgical teams in the learning curve.

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