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Clinical Results of Ascending Aorta and Aortic Arch Replacement under Moderate Hypothermia with Right Brachial and Femoral Artery Perfusion

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Background: Selective antegrade perfusion via axillary artery cannulation along with circulatory arrest under deep hypothermia has became a recent trend for performing surgery on the ascending aorta and aortic arch and when direct aortic cannulation is not feasible. The authors of this study tried using moderate hypothermia with right brachial and femoral artery perfusion to complement the pitfalls of single axillary artery cannulation and deep hypothermia. ***Materials and Methods:*** A retrospective analysis was performed on 36 patients who received ascending aorta or aortic arch replacement between July 2005 and May 2010. The adverse outcomes included operative mortality, permanent neurologic dysfunction and temporary neurologic dysfunction. ***Results:*** Of these 36 patients, 32 (88%) were treated as emergencies. The mean age of the patients was 61.9 years (ranging from 29 to 79 years) and there were 19 males and 17 females. The principal diagnoses for the operation were acute type A aortic dissection (31, 86%) and aneurysmal disease without aortic dissection (5, 14%). The performed operations were ascending aorta replacement (9, 25%), ascending aorta and hemiarch replacement (13, 36%), ascending aorta and total arch replacement (13, 36%) and total arch replacement only (1, 3%). The mean cardiopulmonary bypass time was 209.4±85.1 minutes, and the circulatory arrest with selective antegrade perfusion time was 36.1±24.2 minutes. The lowest core temperature was 24±2.1°C. There were five deaths within 30 post-op days (mortality: 13.8%). Two patients (5.5%) had minor neurologic dysfunction and six patients, including three patients who had preoperative cerebral infarction or unconsciousness, had major neurologic dysfunction (16.6%). ***Conclusion:*** When direct aortic cannulation is not feasible for ascending aorta and aortic arch replacement, the right brachial and femoral artery can be used as arterial perfusion routes with the patient under moderate hypothermia. This technique resulted in acceptable outcomes.

Key words: 1. Aorta, surgery
2. Cardiopulmonary bypass
3. Cerebral protection
4. Hypothermia

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INTRODUCTION

Whenever lesions in the ascending aorta and aortic arch have from direct aortic cannulation, arterial cannulation via the femoral artery has been used for a long time. However, because retrograde aortic dissection and nonperfusion into the true lumen are possible, the technique of selective antegrade perfusion under deep hypothermia using the axillary artery has become a standard perfusion method [1]. Axillary artery cannulation, however, has some drawbacks, including technical problems [2]. Limitations of deep hypothermia have also been reported [3,4]. The benefits of using selective perfusion under moderate hypothermia for brain protection have been reported in recent years [5,6]. Tasdemir et al [7]. reported that cannulation via the brachial artery, instead of the axillary artery, could be useful for a good operative field, a short operation time, and brain protection. Methods for protecting the brain during surgeries of the ascending aorta and the aortic arch have been developing, but remain controversial [8]. Antegrade perfusion via the axillary artery shows better results than retrograde perfusion via the femoral artery; nevertheless, both of them have benefits and drawbacks. We tried to use antegrade and retrograde perfusion at the same time, with the aim of avoiding the fatal problems of either method alone. Also we expected the brachial artery approach to be easier than that of the axillary artery. We report our clinical experiences using the ascending aorta and aortic arch replacement with perfusion via the brachial and femoral arteries under moderate hypothermia.

MATERIALS AND METHODS

Forty-six consecutive patients underwent replacements of the ascending aorta and aortic arch between July 2005 and May 2010. We reviewed 36 patients who had been operated using a perfusion method via the right brachial and femoral artery under moderate hypothermia. Ten patients were excluded because deep hypothermia or two cerebral perfusions including the left common carotid artery were used. We analyzed the preoperative diagnoses, operations, cardiopulmonary bypass time, selective antegrade cerebral perfusion time under circulatory arrest, lowest core temperature, operation mortality rate, and neurologic deficits by retrospectively reviewing the medical records. We defined the postoperative neurologic states showing delirium, irritability, or confusion during the postoperative days with normal brain computed tomography or MRI findings as minor neurologic dysfunction, and the states among the above with definite lesions in brain CT or MRI, or motor dysfunctions, as major neurologic dysfunction. Mean values are described as average±standard deviation.

We positioned the patients in supine position with the right arm abducted, and made incisions in the right axillary and inguinal area to expose the right brachial and the femoral artery at the same time in the manner by Tasdemir et al. [8]. After performing a median sternotomy and exposing the aorta and heart, we administered heparin and inserted cannulae into the right brachial and femoral artery. We directly inserted a 12-Fr cannula (Fem-Flex II®, Edwards Lifesciences, USA) into the brachial artery, or an anastomosed 8-mm graft (Intergard®, Intervascular, USA) to the brachial artery in an end-to-side manner when it was small. We directly inserted an 18-Fr cannula (Fem-Flex II®, Edwards Lifesciences, USA) into the femoral artery.

By reviewing the preoperative CT, we decided to use the femoral artery, which was connected to the true lumen. We connected the cardiopulmonary bypass circuit to the two cannulae using a Y-shaped tube. Venous cannulae were inserted into the IVC and SVC. With the cardiopulmonary bypass running and the rectal temperature lowered to 24°C, we stopped femoral artery perfusion and maintained 40% of total perfusion via the right brachial artery. After blocking the aortic arch vessels with vascular clamps, we performed aortotomy and directly infused cardioplegic solution into the coronary artery ora. Without clamping, we anastomosed the distal aorta, which was open, to a prosthetic bypass graft in an end-to-end manner. We anastomosed the aortic arch vessels, including the innominate artery, to the side of the prosthetic graft in the shape of an island simultaneously or to the prosthetic graft with 4 branches (Intergard®, Maquet GmbH & Co., Germany) in an end-to-end manner, according to the range of the lesions. After finishing the anastomoses of the aortic arch, we anastomosed a 10-mm sized prosthetic graft to the side of the prosthetic graft in an end-to-side manner and used it as an arterial perfusion line. We then clamped the

Table 1. Profile of the patients

Number of patients		36
Age (yr)		61.9 (29～79)
Gender (male : female)		19 : 17
Pre-op Dx	Acute type A dissection	31
	Aneurysmal disease	5
Pre-op	State shock	3
	Cerebral infarction	1
	Unconscious state	2
	Renal dysfunction	3

Table 2. Operation data

Operative procedure	
Ascending aorta replacement	9
Ascending & hemiarch replacement	13
Ascending & total arch replacement	13
Total arch replacement	1
Concomitant procedure	
Coronary artery bypass graft	3
Aortic valve replacement	2
Aortic root reimplantation	1
Mean CPB time (min)	209.4±85.1
Mean SAP time (min)	36.1±24.2
Mean lowest core temperature (^{o}C)	24±2.1

CPB=Cardiopulmonary bypass; SAP=Selective antegrade perfusion.

Table 3. Surgical outcome

Hospital death	5
Diffuse hypoxic brain damage	1
Acute myocardial infarction	1
Mediastintis	1
Bleeding	1
Low cardiac output syndrome	1
Neurologic dysfunction	
Minor	2
Major	6*
Other complications	
Reoperation (bleeding)	1
Mediastinitis	1
Vocal cord palsy	1
Renal failure	3

*=Including pre-op cerebral infarction (1) and pre-op unconscious state (2).

proximal side and started perfusion antegradely. While raising body temperature, we performed proximal anastomosis of the aorta. We verified that cerebral oxygen saturation (cerebral oximeter, INVOS® monitor RS 232, SOMANETICS, USA) was constantly maintained at a certain standard during the entire operation, including during cerebral perfusion.

RESULTS

Of the 36 patients, 32 patients (88%) were operated emergently. The mean age of the patients was 61.9 years (29 to 79 years), and 19 were male and 17 were female. The preoperative diagnoses were acute type A aortic dissection in 31 (86%) patients, and aortic aneurysm without dissection in 5 (14%) patients. There were 3 patients who were in preoperative shock with a creatinine level elevated to over 2.5, showing renal dysfunction (Table 1). We performed ascending aorta replacement in 9 cases (25%), ascending aorta and hemiarch replacement in 13 cases (36%), ascending aorta and total arch replacement in 13 cases (36%), and total aortic arch replacement in 1 case (3%). Operations which were performed simultaneously were a coronary bypass graft in 3 cases, aortic valve replacement in 2 cases, and aortic root reimplantation in 1 case. Mean cardiopulmonary bypass time was 209.4±85.1 minutes, and selective antegrade cerebral perfusion time under the circulatory arrest was 36.1±24.2 minutes. The lowest body core temperature was 24±2.1^{o}C (Table 2). Five patients died within the first 30 days after operation (mortality rate, 13.8%). The causes of death were diffuse hypoxic brain damage in 1, acute myocardial infarction in 1, mediastinitis in l, bleeding in 1, and low cardiac output in l. There were 2 (5.5%) cases of minor neurologic dysfunction defined as delirium, irritability, or confusion during the postoperative days without brain CT and MRI abnormalities. There were 6 (16.6%) cases of major neurologic dysfuction, with patients showing motor dysfunction or definite brain lesions in brain CT or MRI. Diffuse hypoxic brain damage occurred in 1 patient, left brain infarction in 3 patients, and right brain infarction in 2 patients. Of the 6 patients who had major neurologic dysfunctions, 3 patients had preoperative unconsciousness or brain infarction. Other complications were one case of reoperation due to bleeding, one case of mediastinitis and one case of vocal cord palsy. There were no complications related to the cannulation of the right brachial artery in the axillary area. In 3 cases, postoperative renal dysfunction led to hemodialysis (Table 3).

DISCUSSION

Perfusion techniques for protecting the brain during surgeries of the ascending aorta and aortic arch have been controversial for a long time, but are constantly being developed [8]. Specifically, the technique of circulatory arrest under deep hypothermia has made great progress [9]. The complementary addition of retrograde cerebral perfusion has produced better operation results [10]. Though this technique continues to be used widely, Ye et al. [11] has shown through animal experiments that retrograde cerebral perfusion cannot supply complete perfusion to brain tissues. For this reason, surgeries using antegrade perfusion techniques started to be reported [12], demonstrating good operative results. Recently, selective antegrade cerebral perfusion using the axillary artery became a standard perfusion technique for performing ascending aorta and aortic arch operations [1,13-15]. A wide review of the literature shows that axillary artery cannulation has produced better results in the protection of the brain than the femoral artery cannulation. However, Gulbins et al. [8] pointed out that there is a lack of evidence for the axillary artery to be recommended as a standard cannulation site. Direct cannulation into the femoral artery in acute type A aortic dissection can cause retrograde dissection or malperfusion to the true lumen. Dissection of the innominate artery may also occur during axillary artery cannulation, as Imanaka et al. [16] have reported. We therefore tried to perform antegrade and retrograde perfusion simultaneously, in order to provide against the fatal shortcomings of each approach. Applying deep hypothermia requires ample time to raise and lower the temperature and may cause some side effects. Wilde [3] reported that deep hypothermia could keep coagulation down, and change the components of blood. Cooper et al. [4] reported that deep hypothermia could suppress the function of vascular endothelial cells and be involved in cell death, consequently bringing about multiple organ dysfunction. To avoid the drawbacks of deep hypothermia, some trials used selective cerebral perfusion under moderate hypothermia, resulting in excellent brain protection [5,6]. We performed surgeries while lowering the core temperature to around 24^{o}C, but we did not block cerebral perfusion during the entire time of operation. This allowed us to perform operations without the concern of brain damage, and required little time for raising and lowering the core temperature and for cardiopulmonary bypass. There were 3 cases of renal dysfunction, which we believe to be related to preoperative renal dysfunction due to shock, and to be independent of the temperature during operation. There can be technical problems in axillary cannulation [2]. Imanaka et al. [16] reported the fatal dissection of the innominate artery. Tasdemir et al. [7] reported that using the brachial artery instead of the axillary artery for arterial cannulation could provide a good operative field, save operation time, and show good brain protection. We cannulated the brachial and axillary artery at the same time. It took 10 to 15 minutes to cannulate the artery directly and 25 to 30 minutes to connect a prosthetic graft to the brachial artery when it was very small. According to our experiences, the cannulation of the brachial artery was easier and supplied a cleaner operative field than that of the axillary artery. There were no complications related to cannulation. We obtained similar minor cerebral dysfunction results as others reported. The incidence of major cerebral dysfunctions was a bit higher (6 cases, 16.6%). This resulted from our inclusion of 3 cases in which the state of preoperative unconsciousness or brain infarction could have been identified. There was diffuse hypoxic brain damage in 1 case, left brain infarction in 3 cases, and right brain infarction in 2 cases, so we supposed that only right cerebral perfusion might not be the cause of brain damage. The mortality rate (13.8%) was also higher than in previous studies, resulting from a higher rate of acute aortic dissection in our study group.

Even though methods of brain protection for ascending aorta and aortic arch operations are continuously progressing, there is still much debate about which sites are good to cannulate for arterial access, and to what degree it would be effective and safe to lower temperatures.

Merkkola et al. [17] noted that additional methods for brain protection are needed, since cerebral perfusion through the right axillary artery can not supply enough perfusion to the left brain hemisphere in some people, pointing out that the development of Circle of Willis could be incomplete embriologically. Kazui et al. [18] suggested the "Kazui technique", in which antegrade cerebral perfusion is performed with catheters inserted into the three aortic arch branches during aortic arch replacement. Olsson and Thelin [19] suggested bilateral cerebral perfusion via the right axillary artery and the left common carotid artery by inserting a supplementary catheter into the left common carotid artery during circulatory arrest. The authors have also inserted supplementary catheters into the left common carotid artery and the left subclavian artery recently, and will be reporting the results.

CONCLUSION

Using the right brachial and the femoral arteries as routes for arterial access under moderate hypothermia showed satisfactory results when there were lesions which made direct cannulation into the ascending aorta difficult during ascending aorta and aortic arch replacements. Further studies are needed for to improve bilateral cerebral perfusion for more complete brain protection.

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