● Original Article ●

Starting Selective Cerebral Perfusion from the Beginning of Cardiopulmonary Bypass to Prevent Cerebral Embolization During Total Arch Replacement

Mizuho Imamaki, Nobuyuki Nakajima, Masahisa Masuda,
Hitoshi Shimura, Atsushi Ishida, and Masaru Miyazaki

Abstract: *Background:* Preceding selective cerebral perfusion (SCP) isolates cerebral circulation from systemic circulation by starting systemic perfusion and SCP almost simultaneously, as well as by clamping arch vessels. This method aims at preventing cerebral embolization during total arch replacement due to detached atherosclerotic material from the aortic intima, caused by the "sandblasting" effect of the high-velocity jet from an aortic cannula. Neither the safety of starting the SCP at normothermia nor the influence of extended SCP time has been sufficiently clarified. *Methods:* From 1992 to 2001, twenty-seven consecutive patients underwent total arch replacement with this method. *Results:* There were 5 in-hospital deaths (18.5%). Systemic circulatory arrest time was 81.4±24.3 minutes. SCP time was 194.9±30.9 minutes. Patients awoke at the mean time of 6.0±2.7 hours after the operation. Permanent neurological dysfunction was noted in 1 case (3.7%). *Conclusions:* Neither brain complications owing to initiation of SCP at normothermia, nor prolonged emergence from anesthesia to influence of prolonged SCP was seen. Preceding SCP is considered an option in case pedunculated atherosclerotic material or mural thrombus in the ascending and arch aorta is present. (J Jpn Coll Angiol, 2004, **44**: 799–803)

Key words: arch aneurysm, total arch replacement, selective cerebral perfusion, brain protection method

Introduction

Brain complications during operations of arch aneurysm remain a major problem, and various means are used to lower their incidence. The majority of permanent neurological injuries incurred during aortic arch replacement are reported because of strokes resulting from embolic phenomena. Accordingly, a method of reducing the risk of perioperative embolic phenomena may help to improve operative results. Preceding selective cerebral perfusion (SCP) is a method of isolating cerebral circulation from systemic circulation by starting systemic perfusion and SCP almost simultaneously, as well as by clamping arch vessels. It is aimed at preventing cerebral embolization due to detached atherosclerotic material from the ascending and arch aortic intima, caused by the "sandblasting" effect of the high-velocity jet from an aortic cannula. Although the number of cases having pedunculated atheroma, mural thrombus in ascending aorta, or aortic arch is low, I believe this method helps to treat such cases. In addition, the safety of starting SCP at normothermia and influence of extended SCP time need further clarification. This research reviews our experiences with preceding SCP.

Subject and Method

Twenty-seven consecutive patients underwent operations from 1992 to 2001 for degenerative aortic arch aneurysm with preceding SCP. There were 21 men and 6 women, with

Department of General Surgery, Graduate School of Medicine, Chiba University, Chiba, Japan

Received June 4, 2004 Accepted November 22, 2004

ages ranging from 51 to 78 years (mean±standard deviation, 68.4±7.2 years). **Table 1** shows the preoperative patients profiles. Preoperative brain computed tomography (CT) and nonselective cerebral four-vessel angiography were performed for all patients. **Table 2** shows the surgical procedures.

Table 1 Patients profiles

n	27
Male:Female	21:6
Age (yr)	
Mean±standard deviation	68.4±7.2
Range	51–78
Aortic lesions	
Nondissecting	22
Dissecting	5
Acute	0
Chronic	5
Emergency surgery	0

Table 2 Surgical procedures

Total arch replacement	25
+MVR, TAP	1
+s-CABG	1
Total number of cases	27

MVR: mitral valve replacement, TAP: tricuspid annuloplasty, s-CABG: single coronary artery bypass grafting

Operative technique

Even distal arch aneurysm operations were performed through median sternotomy without left thoracotomy or incision of the pleura. The pericardial well was filled with warm saline, and epiaortic echography was performed to examine the condition of the ascending and arch aorta and arch vessels before cannulation. The arch vessels and innominate vein were mobilized and encircled with tapes. The anterior surface of right axillary artery was cut transversely, and then the 10Fr. cannula was inserted into the artery. After a purse string suture was placed on the left common carotid artery, the 10Fr. cannula was inserted into the artery. This 10Fr. cannula was the one used for caval drainage during pediatric cardiac surgery. Immediately after the cardiopulmonary bypass was established with drainage of the superior and inferior caval veins, as well as with perfusion of the ascending aorta, the SCP and clamping of the bases of arch vessels were started. The cannulation sites for SCP were fundamentally the right axillary artery and the left carotid artery. However, perfusion from the left axillary artery was additionally conducted in either of the following 2 situations: 1) the right vertebral artery is more stenotic or hypoplastic than the left vertebral artery as the findings of the preoperative four-vessel study showed, or 2) there is discontinuity of the right and left vertebral artery. This type of SCP by three-vessel perfusion was performed in two cases (7.4%). The flow rate at the time of the start of SCP was about 13 to 15 ml/kg/min, the blood pressure of superficial temporary artery was 50 to 70 mmHg. Then, the flow rate of SCP was gradually reduced as the temperature fell. When the core temperature reached 20 to 25°C, the flow rate of SCP was about 7 to 10 ml/kg/min, and the blood pressure of the superficial temporal artery was 30 to 60 mmHg. An ice bag was set around the head, and topical cooling of the head was also implemented at the same time. When the patient's rectal temperature had gone down to the target level (20°C, or 25°C in recent cases), systemic perfusion was terminated, and the ascending and arch aorta was incised. With a balloon catheter inserted into the ascending aorta, and myocardial protection was achieved by providing St. Thomas solution every thirty minutes through this balloon catheter. After the distal side was trimmed, distal anastomosis was performed with 4-0 polypropylene sutures. When distal anastomosis was completed, low flow perfusion was implemented from the femoral artery for about 30 seconds to flush debris that had fallen into the descending aorta, and to expel air from the descending aorta. The proximal portion of the graft was cross-clamped, and femoral arterial perfusion was stopped. Subsequently, perfusion from the graft branch and rewarming were started. Proximal anastomosis was performed, and the graft was declamped. Finally, the arch vessels (the left subclavian artery, the left common carotid artery, and the brachiocephalic artery, in that order) were individually reconstructed, and the SCP was terminated. After the body temperature returned to normothermia, cardiopulmonary bypass was terminated, and the prosthetic branch

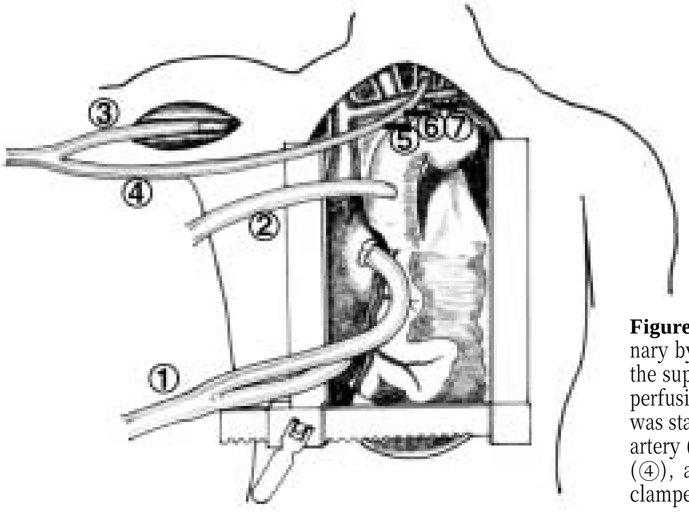

Figure 1 Immediately after the cardiopulmonary bypass was established with drainage of the superior and inferior caval veins (①) and perfusion of the ascending aorta (②), the SCP was started with perfusion of the right axillary artery (③) and the left common carotid artery (④), and the bases of arch vessels were clamped (⑤–⑦).

used for perfusion was resected and closed with sutures. Grafts with four branches (one branch for perfusion after distal anastomosis) were handmade in operating rooms until 1996, whereas, recently, commercially available ready-made grafts (Hemashield Branched Graft, Meadox Medical, Oakland, NJ or InterGard aortic arch type, InterVascular, Cedex, France) have been used.

Results

In-hospital death occurred in 5 cases (18.5%). The causes of death were as follows: Two died of mediastinitis, one of sepsis, one of stroke, which occurred on 6 postoperative day (POD), and one of hypoxemia. The causes of death were not directly related to this preceding SCP. Systemic circulatory arrest time, which was almost equal to the time required for distal anastomosis, was 81.4±24.3 minutes. SCP time was 194.9±30.9 minutes. SCP time was considerably longer than that of total arch replacement with conventional SCP. A possible explantation is that SCP and systemic perfusion were begun almost simultaneously, and it continued until all the anastomoses (distal anastomosis, proximal anastomosis, and arch vessels reconstruction) were completed. Extra corporeal circulation time was 280.6±55.3 minutes. Patients awoke at the mean time of 6.0±2.7 hours after operation. Permanent neurological dysfunction that was thought to occur within 48 hours after surgery was noted in 1 case (3.7%). The patient experienced hemianopsia, with postoperative brain computed tomography (CT) revealed a small low-density area in the left posterior lobe. The cause of brain damage appeared to be embolism of a vertebrobasilar artery by plaque, or a stenotic lesion of the intracranial artery. Another permanent neurological dysfunction was noted in 1 case. The postoperative course of this patient was uneventful, however stroke occurred in POD6. The patient experienced loss of consciousness, with brain CT revealed no low-density area in cerebrum. The cause of brain damage appeared to be brain stem infarction.

Table 3 Operative results

n	27
CA (min)	81.4±24.3
SCP (min)	194.9±30.9
CPB (min)	280.6±55.3
EFA (hour)	6.0±2.7
Stroke	1 (3.7%)
Hospital death	5 (18.5%)

CA: circulatory arrest, SCP: selective cerebral perfusion, CPB: cardiopulmonary bypass, EFA: emergence from anesthesia

Discussion

The majority of permanent neurological injuries that occur during aortic arch replacement are thought to be caused by strokes resulting from embolic phenomena. This represents the significance of preventing cerebral embolization. Femoral arterial cannulation with retrograde aortic perfusion used to be the standard method of aortic arch surgery.[1] But cerebral embolism from atheroma or thrombus in the descending thoracic or abdominal aorta can occur by perfusion through the femoral artery.[2] Therefore, ascending aortic cannulation has come into general use for aortic arch surgery, in order to avoid cerebral embolism. However, ascending aortic perfusion is likely to dislodge mural thrombi or debris when the ascending aorta is involved in the aneurysm or severe atherosclerotic changes. The methods used in such cases are axillary artery cannulation,[3] selected cannulation of the ascending aorta, or cannulation of the transverse arch with a long canula, so that its tip is distal to the left subclavian artery.[4] When these two methods are used together, all or some part of blood flow to the brain passes through the aortic arch. These methods are different from preceding SCP in this respect. Preceding SCP is a method whereby SCP and systemic perfusion start almost simultaneously, and the arch vessels are clamped. Cerebral circulation is isolated from systemic circulation to avoid cerebral embolization due to detachment of atherosclerotic material from the aorta, caused by the "sandblasting" effect of high-velocity jets of blood from the aortic canula. The problem with this method is that the safety of SCP from normothermia is not fully established. Under the conventional SCP, systemic perfusion commences, and when core temperature falls to 18 or 25°C, SCP is started. Safety in regard to optimum flow rate and optimum pressure of SCP under hypothermia has almost been established, based on experiences from many cases. However, the safety of SCP while normothermia declines to hypothermia requires more research. In this research, when temperature reached near normothermia, the pressure of the superficial temporal artery mainly determined the flow rate of SCP. The flow rate of SCP was regulated to remain within a superficial temporal arterial pressure of about 60 mmHg. In recent cases, regional cerebral oxygenation (rSO_2) was monitored. The rSO_2 values before and after starting preceding SCP showed no significant differences in any of the cases. Monitoring of rSO_2 is expected to be useful in determining whether or not SCP is suitable. Kadoi et al. reported that rSO_2 might be sensitive enough to detect subtle changes in regional cerebral oxygenation.[5]

Since cerebral perfusion was performed, in many cases of this research, from the right axillary artery and left common carotid artery, and not from the left subclavian artery, some have pointed out the possibility of ischemia of the vertebrobasilar artery region. We ruled out the necessity for perfusion from the left subclavian artery. In our institution, a non-selective, four-vessel study was performed preoperatively, and the necessity of another perfusion from the left subclavian artery was examined, in all but emergency cases. Thus, when we found neither a significant stenosis, hypoplasty of the right vertebral artery, nor a discontinuity of the right and left vertebral artery we ruled out the possibility of ischemia in the region of vertebrobasilar artery (especially the left posterior inferior cerebellum artery, which originates from left vertebral artery) which had developed through perfusion from right axillar artery and the left common carotid artery. In this research, SCP was implemented from 3 vessels (right axillary, left common carotid, left axillary artery) in 2 cases (7.4%). Ohmi et al. reported the importance of preoperative evaluation of intracranial and extracranial occlusive arterial disease.[6] Therefore, we performed preoperative non-selective, four-vessel studies in all but emergency cases.

The flow rate of SCP decreased as core temperature declined, and SCP was performed with a rectal temperature of 20°C (recently 25°C), with a superficial temporal artery pressure of 30 to 40 mmHg, and at a flow rate of 300 to 400 ml/min. This flow rate and pressure measurement are slightly lower than other reports.[7,8] Once, in our experience, SCP with high flow rate and high pressure resulted in high incidence of cerebral complications.[9] Tanaka et al. reported that the safe range of flow rate for cerebral perfusion during moderate hypothermia is more than 50% of the physiologic level, with a carotid arterial pressure of about 30 mmHg or more.[10]

The second problem with this method is a comparatively longer SCP time than conventional SCP. However, cerebral complications attributable to the long duration of SCP were not seen, and patients awoke from anesthesia without delay. Moreover, the frequency of postoperative transient neurological symptom, including delirium, was not high. SCP differs greatly from circulatory arrest or retrograde cerebral perfusion (RCP) in this regard. Okita et al. reported that the prevalence of transient brain dysfunction was significantly higher in patients who had received RCP, and that a significant correlation was demonstrated between the degree of transient brain dysfunction and the duration of brain circulatory arrest in RCP patients.[11] Ergin et al. reported that the incidence of temporary neurological dysfunction rises linearly with the duration of hypothermic circulatory arrest.[12]

The third problem with this method is the danger of embolism resulting from cannulation to arch vessels and clamping. In this research, canulae were inserted into the right axillary artery and left common carotid artery, and arch vessels were clamped using peripheral vascular clamps. In cases of severe arteriosclerosis, the insertion of canula into arch vessels may cause cerebral embolization. Clamping arch vessels by vascular clamps may carry the same risk. In fact, we occasionally encounter cases in which the proximal portions of arch vessels have severe arteriosclerosis. However, arch vessels distant to some extent from the aortic arch do not usually have severe arteriosclerosis. Thus, it is considered unlikely that complications due to cannulation or clamping occur at such sites. Furthermore, the arch vessels were carefully examined by intraoperative ultrasonic imaging, in order to avoid these complications.[13-15] Intraoperative epiaortic (epiarterial) ultrasonic imaging was performed in all cases to locate the safe site of cannulation and clamping. A diagnosis of atherosclerotic change by epiaortic ultrasonic imaging is expected to be more accurate than by visualization, palpation, and CT. Visualization and palpation generally underestimate the degree and frequency of atherosclerosis.

Controversy over application of this type of preceding SCP to all the cases of total arch replacement still continues. Preceding SCP should be a method to be considered in case pedunculated atherosclerotic material or mural thrombus in the ascending aorta and arch of the aorta is present.

References

1) Crawford ES, Snyder DM: Treatment of aneurysms of the aortic arch. A progress report. J Thorac Cardiovasc Surg, 1983, **85**: 237–246.
2) Westaby S, Katsumata T: Proximal aortic perfusion for complex arch and descending aortic disease. J Thorac Cardiovasc Surg, 1998, **115**: 162–167.
3) Sabik JF, Lytle BW, McCarthy PM et al: Axillary artery: An alternative site of arterial cannulation for patients with extensive aortic and peripheral vascular disease. J Thorac Cardiovasc Surg, 1995, **109**: 885–891.
4) Culliford AT, Colvin SB, Rohrer K et al: The atherosclerotic ascending aorta and transverse arch: A new technique to prevent cerebral injury during bypass: experience with 13 patients. Ann Thorac Surg, 1986, **41**: 27–35.
5) Kadoi Y, Kawahara F, Saito S et al: Effects of hypothermic and normothermic cardiopulmonary bypass on brain oxygenation. Ann Thorac Surg, 1999, **68**: 34–39.
6) Ohmi M, Tabayashi K, Hata M et al: Brain damage after aortic arch repair using selective cerebral perfusion. Ann Thorac Surg, 1998, **66**: 1250–1253.
7) Kazui T, Washiyama N, Muhammad BA et al: Total arch replacement using aortic arch branched grafts with the aid of antegrade selective cerebral perfusion. Ann Thorac Surg, 2000, **70**: 3–9.
8) Tabayashi K, Ohmi M, Togo T et al: Aortic arch aneurysm repair using selective cerebral perfusion. Ann Thorac Surg, 1994, **57**: 1305–1310.
9) Kuwabara M, Nakajima N, Andou M et al: A study on the methods of selective cerebral perfusion on the aortic arch replacement (in Japanese). J Jpn Assn Thorac Surg, 1988, **36**: 466–471.
10) Tanaka H, Kazui T, Sato H et al: Experimental study on the optimum flow rate and pressure for selective cerebral perfusion. Ann Thorac Surg, 1995, **59**: 651–657.
11) Okita Y, Minatoya K, Tagusari O et al: Prospective comparative study of brain protection in total aortic arch replacement: Deep hypothermic circulatory arrest with retrograde cerebral perfusion or selective antegrade cerebral perfusion. Ann Thorac Surg, 2001, **72**: 72–79.
12) Ergin MA, Galla JD, Lansman L et al: Hypothermic circulatory arrest in operations on the thoracic aorta. Determinants of operative mortality and neurologic outcome. J Thorac Cardiovasc Surg, 1994, **107**: 788–799.
13) Marshall WG Jr, Barzilai B, Kouchoukos NT et al: Intraoperative ultrasonic imaging of the ascending aorta. Ann Thorac Surg, 1989, **48**: 339–344.
14) Ohteki H, Itoh T, Natsuaki M et al: Intraoperative ultrasonic imaging of the ascending aorta in ischemic heart disease. Ann Thorac Surg, 1990, **50**: 539–542.
15) Wareing TH, Davila-Roman VG, Barzilai B et al: Management of the severely atherosclerotic ascending aorta during cardiac operations. A strategy for detection and treatment. J Thorac Cardiovasc Surg, 1992, **103**: 453–462.