Surgical management of atherosclerotic aortic arch aneurysms using selective cerebral perfusion: 7-year experience in 52 patients

Northiko Shiiya*, Takashi Kunihara, Michiaki Imamura, Toshifumi Murashita, Yoshiro Matsui, Kcishu Yasuda

Department of Cardiovascular Surgery, Hokkaido University Hospital, N14W5, Kita-ku, Sapporo 060-8648, Japan

Received 7 September 1999; received in revised form 28 December 1999; accepted 17 January 2000

Abstract

Objective. Patients with atherosclerotic aortic arch aneurysms are at greater risk for brain complication. We report our techniques and results of operation using selective cerebral perfusion. Methods. We retrospectively analyzed 52 consecutive patients with atherosclerotic aortic arch aneurysms (mean age, 70 years; range, 53–86 years), who underwent operation between April 1992 and March 1999. The operation was non-elective in 11 patients (21.1%). Concomitant operations included eight coronary artery bypass grafting and one aortic valve replacement. Simultaneous distal aortic reconstruction was performed in three patients. The operation was performed through median sternotomy. To avoid brain embolism, total arch replacement with a branched prosthesis was performed in 48 patients, in an attempt to exclude affected segments of aorta. In addition, retrograde femoral artery perfusion was avoided and cerebral circulation was isolated before aortic manipulation. To achieve even blood flow distribution, we employed perfusion and continuous pressure monitoring of all the three arch vessels. The perfusion rate was 12 ± 2 ml/kg/min and the pressure was kept around 50 mmHg. Deep hypothermic arrest of the lower torso (bladder temperature 22°C) was used during open distal aortic anastomosis. Results. The hospital mortality rate was 11.5% (six of 52), and 7.3% (three of 41) for elective cases. Only one patient (1.9%) developed permanent focal neurological deficit. Six other patients showed temporary brain complications, which was global (dolium) in three and focal in three others. Conclusions. Selective cerebral perfusion is a safe brain protection method, and our strategy seems effective for embolic stroke prevention. © 2000 Elsevier Science B.V. All rights reserved.

Keywords: Aortic arch aneurysm; Atherosclerosis; Aortic arch replacement; Selective cerebral perfusion; Neurological complication

1. Introduction

With the recent progress in the method of brain protection, improved results of aortic arch reconstruction have been reported [1–13]. However, most of these reports deal with both atherosclerotic aneurysms and aortic dissection, and not many authors report results of aortic arch replacement for atherosclerotic aneurysms [14,15]. Beside the risk of cerebral ischemia during reconstruction, patients with atherosclerotic aneurysms have substantial risk of cerebral embolism to the brain. In addition, coronary artery disease and other atherosclerotic diseases are frequently associated [1,2,4,8], which may significantly influence the operative outcome.

We report our results of aortic arch replacement for atherosclerotic aneurysms on 52 consecutive patients in recent 7 years. The technique of operation consisted of selective cerebral perfusion [16] for brain protection in all cases and total arch replacement with three separate grafts for reconstruction of the arch vessels in 92% (48 of 52). These branch grafts were connected to the main graft before use (branched prosthesis). The impact of our technique in preventing brain complications will be discussed.

2. Materials and methods

2.1. Patients' profiles

From April 1992 through March 1999, 52 patients underwent aortic arch replacement for atherosclerotic aneurysms in our service. There were 42 men and ten women, with a mean age of 70 ± 7 years (range 53–86 years). One redo operation for a recurrent aneurysm around the previous patch reconstruction site was included. Aneurysms were
symptomatic in 25 patients, and non-selective operation was performed in 11 of them (21%). One rupture and two pulmonary fistulae were included. The remainder of the patients had elective operations. The aneurysms were fusiform in 40 patients, while they were sacciform in 12 patients. Location of the fusiform aneurysms was distal (aneurysms that involve the descending aorta and extend into the aortic arch) in 35 patients, proximal (aneurysms that extend from the ascending aorta to the aortic arch) in three patients and diffuse (aneurysms that extend from the ascending aorta to the descending aorta) in two. In three patients, the aneurysm was extended into the distal descending thoracic or thoracoabdominal aorta. Maximum diameter of the aneurysm was 66 ± 13 mm.

Preoperative coronary angiography was performed in all but ten patients, and significant coronary artery stenoses were found in 11 patients (26%). Concomitant coronary artery bypass grafting (CABG) was performed in eight cases and preoperative PTCA in one. History of cerebrovascular disease was present in 15 patients (29%). Cerebral infarction was present in seven, transient ischemic attack in five, and subarachnoid hemorrhage in three. As the preoperative brain evaluation, we performed brain CT or MRI, carotid duplex scan, and MR angiogram. Carotid duplex scan was performed to find a potential embolic source that might be dislodged by brain perfusion. Brain MR angiogram was performed to determine the dominant vertebral artery, patency of the Willis circle, and presence of occlusive lesions, to achieve even blood flow distribution during cerebral perfusion period. Thirty-two of 37 patients without history of cerebrovascular disease underwent brain CT scan or MRI before operation, and 17 of them (53%) had an evidence of subclinical lacunar infarction of the brain. Other concurrent atherosclerotic diseases included a separate aneurysm on the thoracoabdominal aorta (two patients) or descending thoracic aorta (two patients), an abdominal aortic aneurysm (12 patients) and an aortoiliac occlusive disease (two patients). In addition, three patients had a history of abdominal aortic replacement, one had a history of descending thoracic replacement, and one had undergone thoracoabdominal replacement. Two descending thoracic aneurysms extending from the aortic arch and one separate thoracoabdominal aneurysm were replaced simultaneously, while the elephant trunk technique was employed in a patient with a thoracoabdominal aneurysm extending from the arch for staged operation. Both abdominal aortic aneurysms (seven patients) and aortoiliac occlusive disease (one patient) were treated in two stages. One patient underwent concomitant aortic valve replacement.

2.2. Operative technic (Fig. 1)

The operations were performed through a median sternotomy. An arterial cannula was placed in the proximal ascending aorta if this region is not affected by the atheromatous disease, which was determined on the basis of the findings of preoperative CT scan or intraoperative epicardial echocardiography. Alternative cannulation sites, which included the femoral artery in three patients and the brachiocephalic trunk in one, were used when the ascending aorta was not considered suitable for cannulation. Cardiopulmonary bypass was instituted, the left ventricle was vented through the right superior pulmonary vein and core cooling was started. During this period, cannulation for selective cerebral perfusion was performed. To reduce the risk of atheroembolism to the brain that may be associated with aortic manipulation, selective cerebral perfusion was established and cerebral circulation was isolated from systemic one before manipulation of the arch. Our technique of selective cerebral perfusion has been described previously in detail [16]. Briefly, the innominate artery and left common carotid artery were directly cannulated, if atheromatous disease were not found in these vessels by a preoperative ultrasound duplex scan. This was the case in all but five patients. The

---

Fig. 1. Schematic drawings of the operative technique. (1) cannulation in the proximal ascending aorta and core cooling, (2) cannulation for cerebral perfusion, (3) open distal aortic anastomosis, (4) rewarming through the fourth branch graft, (5) proximal aortic anastomosis, (6) reconstruction of arch vessels.
left subclavian artery was perfused through a balloon catheter that was introduced through the aortic arch after the aneurysm was opened in 34 patients, cannulated through a stab wound in 12 patients or perfused from the axillary artery in two patients. In four of 11 patients who underwent operations before September 1993, the left subclavian artery was not perfused because the right vertebral artery predominately supplied the basilar artery. Total amount of blood flow to these branches was regulated to 12 ± 2 ml/kg per min by a single roller pump independent from the systemic one. Pressures of bilateral radial and left superficial temporal arteries were continuously monitored to achieve even distribution of blood flow, and pressure of the left superficial temporal artery was kept around 80 mmHg.

Our principal technique of aortic arch reconstruction is based on the use of a branched aortic prosthesis that is provided with four side branches (8 or 10 mm in diameter), three for reconstruction of the arch vessels and one for blood inflow after reconstruction. When the bladder temperature reached 22°C, systemic blood perfusion was stopped and a cold blood cardioplegic solution was given. We carried out the distal aortic anastomosis first, usually from within the aneurysm, using the technique of open aortic anastomosis. Then a clamp was placed on the branched aortic prosthesis, systemic perfusion was resumed through the fourth side branch, and the patient was gradually rewarmed. Proximal aortic anastomosis was then carried out just above the coronary arteries so that aortic crossclamping site and the hole of cardioplegic needle were resected, and coronary blood flow was restored. Finally, remaining three branch grafts were anastomosed in an end-to-end fashion to the three branches of the aortic arch with the origins of these branches resected, and selective cerebral perfusion was discontinued. Concomitant operations such as CABG were performed either during the cooling period or during the rewarming period before reconstruction of the arch vessels.

The type and extent of aortic reconstruction are summarized in Fig. 2. Forty-eight of 52 patients (92%) underwent total arch replacement with a branched prosthesis, in an attempt to exclude affected segments of aorta from the blood stream.

2.3. Definitions

Neurologic complications were classified as follows: temporary or permanent, global or focal. Temporary global complication corresponded to the temporary neurological dysfunction as defined by Ergin and co-workers [5,17], and included the occurrence of postoperative confusion, agitation, delirium, prolonged obtundation, or transient parkinsonism without any localizing neurologic signs. Its severity was graded from 1 to 5 according to the method of Ergin and co-workers [17]. Permanent neurologic complication was defined as the presence of neurologic deficits persisting at discharge from the hospital. Strokes were defined as transient or permanent neurologic deficits with localizing neurologic signs and corresponding new defects on CT scans or MRI, according to Ergin and co-workers [5].

3. Results

The overall hospital mortality rate was 12% (six of 52), and it was 7% (three of 41) for elective cases. The cause of
death was cardiac in three, infection in two and bleeding in one. All other patients were discharged from the hospital. Perfusion data were summarized in Table 1.

3.1. Neurologic outcome

Only one patient (2%) developed permanent focal neurologic deficit. Six other patients showed temporary brain complications, which was global in three (6%) and focal in three others (6%). The severity of temporary global dysfunction was grade 1 (simple confusion) in two and grade 2 (confusion + lethargy) in one patient. Radiologic evidence of new lesion was present in two of these seven, and the stroke rate was 4%. All other patients recovered their consciousness within a day just like the patients who underwent standard cardiac procedures.

3.2. Other postoperative complications

Respiratory failure that required prolonged ventilatory support (more than 72 h) occurred in eight patients. Bleeding that required reexploration occurred in three patients. Deep sternal wound infection occurred in one patient, which was fatal.

4. Discussion

Hypothermic circulatory arrest [4,5,18], retrograde cerebral perfusion [8–10,12,13] and selective cerebral perfusion [6,7,11,14,16] have been used for brain protection during aortic arch reconstruction. Reported results suggest that all these three techniques provide adequate protection of the brain from ischemia with their own advantages and disadvantages. However, the incidence of the brain complication is still high for the atherosclerotic aneurysms, which suggests that most of these complications are results of embolic events [4,5,17].

From this point of view, our technique was designed to reduce the risk of brain embolism that is related to the manipulation of the atheromatous aortic arch or to the use of cardiopulmonary bypass. To reduce the risk of brain embolism that is related to the aortic arch manipulation, we isolated cerebral circulation before aortic arch manipulation, and tried to exclude the native aortic arch and the origins of the branches from blood stream by adopting total arch replacement with separate grafts for reconstruction of the branches in every case. There are increasing evidences that atherosclerotic arch could account not only for cerebral complications during cardiopulmonary bypass [19] but also for spontaneous strokes in some patients [20]. In addition, we frequently found loose atheromatous debris in the origins of the branches. Therefore, distal lesion was also treated by total arch replacement rather than distal arch repair. This strategy is supported by the report by Ergin and colleagues [5]. They have reported that in the presence of clots or atheroma, prevalence of stroke was around 45% when proximal or distal repair was done, whereas it was significantly lower (9%) when total arch replacement was performed.

To reduce the risk of brain embolism that is related to the use of cardiopulmonary bypass, we carefully decided the route of arterial inflow. In principle, we cannulated the proximal part of the ascending aorta so that arterial jet might not be directed toward the atheromatous aortic arch. In addition, we tried to avoid retrograde femoral artery perfusion as far as possible, and antegrade flow was achieved through the fourth branch graft after completion of distal aortic anastomosis. Several authors have reported that retrograde arterial perfusion is associated with the risk of strokes [21]. This may be especially true when atherosclerotic disease such as aortoiliac occlusive disease or a downstream aneurysm exists, which is often the case in atherosclerotic aneurysms. In the present series, 21 patients (40%) had such downstream lesion.

As a result of these technical modifications, neurologic complication rate in our patients was low as compared with previous reports [3–5,9–14]. Ergin and colleagues have reported that advanced age and atherosclerotic aneurysms were important predictors of strokes [5]. In their series, the incidence of strokes was 21% for the patients aged more than 60 years. Similarly, Svensson and colleagues have reported that the risk of stroke was higher in patients with atherosclerotic lesion and advanced ages [4]. Considering that not only the atherosclerotic aneurysms were included in the Ergin's series and 88% (46 of 52) of our patients were more than 60 years old, and that similarly low stroke rate was reported by the group that used similar techniques to ours [6], we would like to conclude that our technique has a preventive effect against embolic strokes.

Another important finding in the present study was markedly low incidence of temporary neurologic dysfunction. There is an evidence that temporary neurologic dysfunction is not a benign process but is associated with long-lasting neuropsychological deficit [17]. Ergin and colleagues, using hypothermic circulatory arrest as a brain protection method, have reported that age and duration of circulatory arrest are the dominant factors predicting temporary neurologic dysfunction, which occurred in 29% of their patients aged 60 years and older [5]. Orcita and associates, using retrograde cerebral perfusion, have reported that advanced age and atherosclerotic aneurysms are the risk factors for delirium, which occurred in 25% of the patients [10]. Although many factors have been reported to be associated with postoperative temporary neurologic dysfunction, which includes
patients' factors, hemodynamic factors, microembolism, hemorrhage, surgical stress, and anesthetic drugs, ischemia-reperfusion process seems more or less involved in its mechanism. Therefore the low incidence of temporary neurologic dysfunction observed in our series may be due to the use of selective antegrade cerebral perfusion, which resulted in less ischemia-reperfusion injury. Other studies have demonstrated that selective cerebral perfusion provides adequate cerebral protection for a longer period than hypothermic circulatory arrest [6,7,16]. In fact, our patients tolerated well up to 4 h of selective cerebral perfusion. High stroke rates reported in the early study that used cerebral perfusion technique was no more applicable to the modern techniques, in which lower perfusion rate and direct cannulation to the unaffected branches were employed [6,7,11,16]. The major drawback of selective cerebral perfusion is its complexity. However, we believe that cardiotomy bypass time will not be prolonged by this technique because cannulation for perfusion can be performed during the cooling period and reconstruction of the branches can be performed during the rewarming phase. In addition, body temperature need not be as low as that during circulatory arrest when antegrade perfusion to the three arch vessels is used.

The overall mortality rate of 12% in this group of patients compares favorably with those in other series [1–5,8–14,18]. Ergin and colleagues have reported a mortality rate of 18% for atherosclerotic aneurysms and 21% for patients older than 60 years of age [5]. Laas and colleagues have reported a mortality rate of 12% for aortic arch aneurysms [3]. Because predominant cause of early death was cardiac in most reports [1–4,18], prevalence of concurrent coronary artery disease has been reported to be high [1,2,4,8], we routinely performed coronary angiography before operation. As a result, 11 patients had coronary artery disease and eight underwent concomitant bypass grafting. Similar rate of concomitant operation has been reported by others [1,2,4,8]. Although elevated early mortality rate has been reported in patients who underwent concomitant CABG [1], no early death (one hospital death due to infection) occurred in our patients. We performed CABG and proximal aortic anastomosis before reconstruction of the arch vessels to shorten the period of myocardial ischemia. This order of operation, which became possible because of the reliability of selective cerebral perfusion to protect the brain for a prolonged period, might have contributed to successful CABG in our patients.

In conclusion, results of the present report suggest that selective cerebral perfusion is a safe brain protection method, and our strategy seems effective for embolic stroke prevention.

5. Addendum

Since the submission of the abstract, four additional patients underwent operation on the same principle. The results were excellent, with no mortality or morbidity. Two of them were performed without heterogeneous blood transfusion.

References


