SURGERY FOR ACQUIRED CARDIOVASCULAR DISEASE

IMPROVED RESULTS OF ATHEROSCLEROTIC ARCH ANEURYSM OPERATIONS WITH A REFINED TECHNIQUE

Teruhisa Kazui, MD
Naoki Washiyama, MD
Bashar A. H. Muhammad, MBBS
Hitoshi Terada, MD
Katsushi Yamashita, MD
Makoto Takinami, MD

For related editorial, see p. 425.

Objective: We sought to analyze the postoperative hospital mortality and postoperative neurologic dysfunction in patients who had total arch replacement for atherosclerotic arch aneurysms using our recent refined technique.

Methods: Between June 1997 and April 2000, 50 consecutive patients underwent total arch replacement with an aortic arch branched graft for atherosclerotic arch aneurysms. Their mean age was 71 ± 7 years (range, 57-87 years). Forty-eight (96%) patients were operated on electively, and the remaining 2 (4%) were operated on an emergency basis because of rupture of aneurysm. All operations were performed with hypothermic extracorporeal circulation, selective cerebral perfusion for cerebral protection during aortic arch repair, and systemic circulatory arrest during distal graft anastomosis. A total of 19 concomitant procedures were done in 17 patients. Mean selective cerebral perfusion time was 78.1 ± 16.5 minutes.

Results: Overall in-hospital mortality was 2% (95% confidence intervals, 0%-5.9%). On univariable analysis, permanent neurologic dysfunction was the only risk factor for in-hospital mortality. Postoperative temporary and permanent neurologic dysfunctions were 4% (95% confidence intervals, 0%-9.4%) and 4% (95% confidence intervals, 0%-9.4%), respectively. On univariable analysis, cardiopulmonary bypass time was the only risk factor for temporary neurologic dysfunction, and history of cerebrovascular disease was the only risk factor for permanent neurologic dysfunction. There was no significant correlation between selective cerebral perfusion time and temporary and permanent neurologic dysfunction.

Conclusion: Integrated cerebral protective effect of antegrade selective cerebral perfusion and total arch replacement with an aortic arch branched graft could substantially reduce in-hospital mortality and postoperative neurologic dysfunction in patients with atherosclerotic arch aneurysms. (J Thorac Cardiovasc Surg 2001;121:491-9)

With recent improvement in surgical technique of aortic arch reconstruction and cerebral protection methods during aortic arch repair, outcomes of aortic arch aneurysm operations have remarkably improved. However, mortality and morbidities, including neuro-

logic dysfunction, in patients who undergo aortic arch repair for atherosclerotic aneurysms remain high because of advanced age and comorbidities.¹⁻⁴ In our previous experience with 220 patients who underwent aortic arch operations for various indications, including atherosclerotic arch aneurysm (100 patients), the in-hospital mortality was 12.7%, and the postoperative permanent and temporary neurologic dysfunctions were 3.3% and 6%, respectively.⁵

The purpose of the present study was to evaluate whether our recent refined technique was able to reduce the in-hospital mortality and postoperative

From the First Department of Surgery, Hamamatsu University School of Medicine, Hamamatsu, Japan.

Copyright © 2001 by The American Association for Thoracic Surgery

0022-5223/2001 \$35.00 + 0 12/1/112469

doi:10.1067/mtc.2001.112469

Table I. *Extent of the operative procedure*

<i>Extent</i>	<i>No. of patients</i>
Asc Ao + TAR	6
Asc Ao + TAR + composite graft	1
Asc Ao + TAR + LVA reconstruction	1
Asc Ao + TAR + AAA repair	1
Asc Ao + TAR + Des Ao	27
Asc Ao + TAR + Des Ao + LVA reconstruction	2
Asc Ao + TAR + Des Ao + CABG	7
Asc Ao + TAR + Des Ao + AVR + CABG	2
Asc Ao + TAR + Des Ao + AVR + A-F bypass	1
Asc Ao + TAR + Des Ao + AAA repair	2
Total	50

Asc Ao, Ascending aortic replacement; TAR, total arch replacement; LVA, left vertebral artery; AAA, abdominal aortic aneurysm; Des Ao, descending aortic replacement; AVR, aortic valve replacement; A-F, aorto-bifemoral.

neurologic dysfunction in this particular group of patients.

Material and methods

Patient profile. Fifty consecutive patients with atherosclerotic arch aneurysms underwent total arch replacement with the aid of hypothermic cardiopulmonary bypass (CPB) and antegrade selective cerebral perfusion (SCP) between June 1997 and April 2000. The patients ranged in age from 57 to 86 years, with a mean of 71 ± 7 years. Thirty-three (66%) were male patients, and 17 (34%) were female patients. Six (12%) patients had an aneurysm that involved the ascending aorta and the whole of the arch, 10 (20%) had an aneurysm involving the entire aortic arch, and 34 (68%) had distal arch aneurysm with or without extension to the descending aorta. Forty-eight (96%) patients were operated on electively, and the remaining 2 (4%) were operated on on an emergency basis because of rupture of aneurysm.

Preoperative comorbidities included coronary artery disease in 11 (22%) patients; chronic obstructive pulmonary disease in 6 (12%) patients; aortic valvular disease in 3 (6%) patients; history of cerebrovascular disease in 9 (18%) patients, including old cerebral infarct in 6 (12%) patients; chronic renal failure in 4 (8%) patients, with 2 requiring hemodialysis; abdominal aortic aneurysm in 3 (6%) patients; aortoiliac occlusive disease in 1 (2%) patient; hypertension in 26 (56%) patients; and diabetes mellitus in 2 (4%) patients. Six (12%) patients had previous operations, including aortoiliac graft replacement for abdominal aortic aneurysm in 5 (10%) patients and descending aortic graft replacement for descending aortic aneurysm in 1 (2%) patient. Another 3 (6%) patients had previous percutaneous transluminal coronary angioplasty for coronary artery disease.

Preoperative aortography or digital subtraction angiography, including cerebral 4-vessel angiography, and cerebral computed tomography were performed in all patients undergoing elective procedures.

Operative technique. All operations were performed through a median sternotomy, with an extension of the incision to the left supraclavicular region. Table I summarizes the extent of the operative procedure done in this series. The details of hypothermic CPB and antegrade SCP have been described previously.^{6,7} During CPB, arterial blood pH was managed according to the alpha-stat strategy. As for the site of arterial cannulation for CPB, the ascending aorta was selected in the recent 34 (68%) patients, whereas the femoral artery was selected in the remaining 16 (32%) patients. Before the ascending aorta was cannulated, epiaortic ultrasonography scanning and transesophageal echocardiography were routinely performed to assess whether atherosclerotic plaques are present in the ascending aorta and the aortic arch.

For SCP, a newly developed flexible perfusion cannula (Fuji System Corporation, Tokyo, Japan) was used in the most recent patients. This cannula has two lumina, one for blood perfusion and the other for pressure monitoring. A balloon at the tip prevents slippage of the cannula when inflated after cannulation of the arch vessels. The cannula, because of its flexible metallic support, can be bent manually at the desired angle without causing any luminal compromise. This property allows the surgeon to place the cannula toward the patient's head side so that it does not obscure the operative field. The temperature of the antegrade cerebral perfusate was 22°C during SCP.

Real-time intraoperative monitoring of SCP is important to assess whether cerebral perfusion is adequate. First, we monitor the perfusion pressure and flow rate of SCP. For the perfusion pressure of SCP, the right radial artery pressure and the bilateral catheter tip pressure are routinely monitored. Two-channel serial electroencephalography to monitor the cerebral electrical activity and 2-channel near infrared spectroscopy (Hamamatsu Photonix, Hamamatsu, Japan) to estimate regional cerebral oxygenation are used. These techniques also assess discrepancies of cerebral circulation between the 2 cerebral hemispheres. In addition to these, internal jugular venous oxygen saturation is used to monitor cerebral oxygen consumption.

Vascular prostheses used in all patients were commercially available collagen-pretreated aortic arch grafts with 4 limbs (Hemashield Branched Graft; Meadox Medical, Oakland, NJ). The details of our recent technique of total arch replacement with an aortic arch branched graft for atherosclerotic aneurysm of the aortic arch are depicted in Fig 1. Under SCP with systemic circulatory arrest at a rectal temperature of 22°C, the descending aorta just below the aneurysm is completely transected (Fig 1, B). The distal side of the arch graft with 4 limbs is anastomosed to the stump of the descending aorta by a 4-0 monofilament running suture with Teflon felt reinforcement (Fig 1, C). The arch graft proximal to the fourth limb is crossclamped, and systemic perfusion to the lower half of the body is started from the fourth limb of the arch graft (Fig 1, D). The third limb is then anastomosed to the left subclavian artery by a 5-0 monofilament running suture. Then the arch graft proximal to the third limb is crossclamped, and rewarming by means of CPB is started (Fig 1, E). The proximal side of the arch graft is sutured to the stump

Fig 1. Schema of our recent surgical technique of total arch replacement with aortic arch branched graft for atherosclerotic aneurysm.

of the ascending aorta by a 4-0 monofilament running suture with Teflon felt reinforcement, the aortic arch graft is declamped, and coronary circulation is started. The first limb of the arch graft is anastomosed to the innominate artery with a 5-0 monofilament running suture (Fig 1, F), and the second limb is anastomosed to the left common carotid artery in the same fashion (Fig 1, G). After the extracorporeal circulation is terminated, the fourth limb of the arch graft, which is used for antegrade systemic perfusion, is resected (Fig 1, H).

The extent of aortic replacement was as follows: replacement of the ascending aorta and total arch was performed in 9 (18%) patients, and replacement of the ascending aorta, total arch, and proximal descending aorta (defined as descending aortic replacement with the distal anastomosis located from 5 to 10 cm distal to the origin of the left subclavian artery) was performed in 41 (82%) patients. Concomitant procedures included composite graft replacement with coronary reimplantation in 1 (2%) patient, coronary artery bypass grafting (CABG) in 9 (18%) patients, aortic valve replacement in 3 (6%) patients, left vertebral artery reconstruction in 3 (6%) patients where the left vertebral artery directly originated from the aortic arch, aortoiliac graft replacement for abdominal aortic aneurysm in 3 (6%) patients, and aortobifemoral bypass grafting for aortoiliac occlusive disease in 1 (2%) patient. Aortoiliac graft replacement and aortobifemoral bypass grafting were performed through the transperitoneal approach after termination of CPB and neutralization of heparin.

Statistical method. The continuous data in this study are expressed as the mean $\pm$ SD, and categorical variables are expressed as percentages.

We analyzed 33 preoperative, perioperative, and postoperative risk factors for their possible effect on in-hospital mortality and 31 risk factors for their possible effect on postoperative neurologic outcome (Table II). First, all the independent variables were analyzed by a univariable analysis (Fisher exact test or Mann-Whitney analysis) to determine whether any single variable influenced in-hospital mortality and postoperative neurologic outcome. Variables that achieved *P* values of less than .2 in the univariable analysis were examined with multivariable analysis by using forward stepwise logistic regression to study their independent predictability in influencing in-hospital mortality and postoperative neurologic outcome. Survival was estimated by the Kaplan-Meier method, with variability expressed as $\pm$ 95% confidence intervals (CI). All computations were performed with the SPSS 6.1 for UNIX (SPSS, Inc, Chicago, Ill) and Statview 5.0 (SAS Institute, Cary, NC) statistical software packages.

Results

In-hospital mortality. There were no operative deaths or 30-day mortality. One of the 50 patients died during hospitalization, for an in-hospital mortality of

Table II. Univariable analysis of in-hospital mortality and neurologic outcome

Variables		Patients		In-hospital mortality		P value	Temporary ND		P value	Permanent ND		P value
		No.	%	No.	%		No.	%		No.	%	
Sex												
	Male	33	66	0	0	NS	2	6	NS	1	3	NS
	Female	17	34	1	6		0	0		1	6	
Age (y)												
	50-59	4	8	0	0	NS*	0	0	NS*	0	0	NS*
	60-69	13	26	0	0		0	0		0	0	
	70-79	29	58	1	3		1	3		2	7	
	≥80	4	8	0	0		1	25		0	0	
Hypertension												
	Yes	26	52	1	4	NS	1	4	NS	2	8	NS
	No	24	48	0	0		1	4		0	0	
Diabetes												
	Yes	2	4	0	0	NS	0	0	NS	1	50	.08
	No	48	96	1	2		2	4		1	2	
CAD												
	Yes	11	22	1	9	NS	1	9	NS	1	9	NS
	No	39	78	0	0		1	3		1	3	
COPD												
	Yes	6	12	0	0	NS	0	0	NS	0	0	NS
	No	44	88	1	2		2	5		2	5	
AR												
	Yes	3	6	0	0	NS	0	0	NS	0	0	NS
	No	47	94	1	2		2	4		2	4	
Old cerebral infarct												
	Yes	6	12	0	0	NS	1	17	NS	1	17	NS
	No	44	88	1	2		1	2		1	2	
CVD												
	Yes	9	18	1	11	NS	1	11	NS	2	22	.03
	No	41	82	0	0		1	2		0	0	
Chronic renal failure												
	Yes	4	8	0	0	NS	0	0	NS	0	0	NS
	No	46	92	1	2		2	4		2	4	
AAA												
	Yes	3	6	0	0	NS	0	0	NS	0	0	NS
	No	47	94	1	2		2	4		2	4	
Aortoiliac occlusion												
	Yes	1	2	0	0	NS	0	0	NS	0	0	NS
	No	49	98	1	2		2	4		2	4	
Previous aortic operation												
	Yes	6	12	0	0	NS	0	0	NS	0	0	NS
	No	44	88	1	2		2	5		2	5	
Emergency												
	Yes	2	4	0	0	NS	0	0	NS	0	0	NS
	No	48	96	1	2		2	4		2	4	
Extent of replacement												
	Asc Ao + TAR	9	18	0	0	NS	0	0	NS	0	0	NS
	Asc Ao + TAR + Des Ao	41	82	1	2		2	5		2	5	
CABG												
	Yes	9	18	1	11	NS	1	11	NS	1	11	NS
	No	41	82	0	0		1	2		1	2	
Composite G												
	Yes	1	2	0	0	NS	0	0	NS	0	0	NS
	No	49	98	1	2		2	4		2	4	
AVR												
	Yes	3	6	0	0	NS	1	33	NS	0	0	NS
	No	47	94	1	2		1	2		2	4	

Continued.

Table II. *Cont'd*

Variables		Patients		In-hospital mortality		P value	Temporary ND		P value	Permanent ND		P value
		No.	%	No.	%		No.	%		No.	%	
AAA repair	Yes	3	6	0	0	NS	0	0	NS	0	0	NS
	No	47	94	1	2		2	4		2	4	
A-F bypass	Yes	1	2	0	0	NS	0	0	NS	0	0	NS
	No	49	98	1	2		2	4		2	4	
Arterial cannulation site	Femoral	16	32	0	0	NS	1	6	NS	1	6	NS
	Asc Ao	34	68	1	3		1	3		1	3	
CPB time (min)	100-149	16	32	0	0	NS*	0	0	.03	0	0	NS*
	150-199	33	66	0	0		0	0		1	3	
	≥200	11	22	1	9		2	18		1	9	
Ao CC time (min)	60-89	24	48	0	0	NS*	0	0	NS*	0	0	NS*
	90-119	13	26	0	0		0	0		1	8	
	120-149	7	14	1	14		1	14		1	14	
	≥150	6	12	0	0		1	17		0	0	
SCP time (min)	40-59	7	14	0	0	NS*	0	0	NS*	0	0	NS*
	60-79	19	38	0	0		0	0		1	5	
	80-99	19	38	1	5		1	5		1	5	
	≥100	5	10	0	0		1	20		0	0	
SCA time (min)	0-29	15	30	0	0	NS*	0	0	NS*	0	0	NS*
	30-59	30	60	1	3		1	3		2	7	
	≥60	5	10	0	0		1	20		0	0	
Postoperative temporary ND	Yes	2	4	0	0	NS	—	—	—	—	—	—
	No	48	96	1	2	NS	—	—	—	—	—	—
Postoperative permanent ND	Yes	2	4	1	50	.04	—	—	—	—	—	—
	No	48	96	0	0		—	—	—	—	—	—
Rethoracotomy for hemorrhage	Yes	2	4	0	0	NS	0	0	NS	0	0	NS
	No	48	96	1	2		2	4		2	4	
Postoperative pulmonary failure	Yes	6	12	1	17	NS	0	0	NS	1	17	NS
	No	44	88	0	0		2	5		1	2	
Postoperative renal failure	Yes	3	6	1	33	NS	1	33	NS	1	33	NS
	No	47	94	0	0		1	2		1	2	
Postoperative liver dysfunction	Yes	1	2	0	0	NS	0	0	NS	0	0	NS
	No	49	98	1	2		2	4		2	4	
Postoperative LOS (IABP)	Yes	1	2	1	100	.08	0	0	NS	1	100	NS
	No	49	98	0	0		2	4		1	2	
Postoperative A-E fistula	Yes	1	2	0	0	NS	0	0	NS	0	0	NS
	No	49	98	1	2		2	4		2	4	

NS, Not significant; CAD, coronary artery disease; COPD, chronic obstructive pulmonary disease; AR, aortic regurgitation; CVD, cerebrovascular disease; AAA, abdominal aortic aneurysm; Asc Ao, Ascending aortic replacement; TAR, total arch replacement; Des Ao, descending aortic replacement; composite G, composite graft replacement; AVR, aortic valve replacement; A-F, aortobilateral femoral bypass; Ao CC, aortic crossclamping; SCA, systemic circulatory arrest; ND, neurologic dysfunction; LOS, low cardiac output syndrome; IABP, intra-aortic balloon pump; A-E, aorto-esophageal fistula.

*Kruskal-Wallis analysis was not possible because of the small patient number in each group. Therefore, the variables in patients with or without postoperative neurologic dysfunction were compared by the Mann-Whitney analysis.

Fig 2. Patient distribution according to SCP time.

2% (95% CI, 0%-5.9%). One patient who had an ischemic stroke after a prolonged period of hypoxia and shock caused by endotracheal intubation trouble after the termination of extracorporeal circulation died of aspiration pneumonia 6.4 months after the operation. In-hospital mortality for patients who had permanent neurologic dysfunction was 50%, whereas the incidence was 0% for those without permanent neurologic dysfunction. Table II shows univariable analysis of in-hospital mortality and neurologic outcome. It revealed that permanent neurologic dysfunction was the only significant risk factor of in-hospital mortality. On multivariable analysis, however, no significant independent predictor of in-hospital mortality was found.

In-hospital morbidity. Transient neurologic dysfunction, defined as postoperative confusion, agitation, and delirium with negative computed tomography results and complete resolution symptoms before discharge, was observed in 2 (4.0%) of the 50 patients (95% CI, 0%-9.4%). Univariable analysis revealed that CPB time was the only variable to significantly influence temporary neurologic dysfunction (Table II). On multivariable analysis, however, no significant independent predictor of temporary neurologic dysfunction was found.

Permanent neurologic dysfunction, defined as permanent neurologic deficits with localizing neurologic signs and a corresponding new defect observed on computed tomographic scanning, was noted in only 2 (4.0%) of the 50 patients (95% CI, 0%-9.4%). One patient sustained ischemic stroke because of endotracheal intubation trouble after the termination of extracorporeal circulation, and the other underwent embolic stroke. The patient with an embolic stroke recovered well and was discharged with mild hemiplegia. Cause of the stroke in this case might have been distal emboli

from the femoral artery perfusion. Univariable analysis indicated that history of cerebrovascular disease was the only variable to significantly influence permanent neurologic dysfunction (Table II). Multivariable analysis, however, did not show any independent predictor of permanent neurologic dysfunction. The incidence of postoperative temporary and permanent recurrent laryngeal nerve injury was 10% (5 cases) and 6% (3 cases), respectively. There was, however, no incidence of phrenic nerve injury. Other in-hospital morbidities included hemorrhage requiring a repeat thoracotomy in 2 (4%) patients, pulmonary failure requiring support with a respirator for more than 5 days after the operation in 6 (12%) patients, renal failure (defined as a blood urea nitrogen level > 70 mg/dL or a serum creatinine level of > 3.0 mg/dL) in 3 (6%) patients, liver dysfunction (defined as a total bilirubin level > 3.0 mg/dL or glutamic pyruvic transaminase level > 100 U) in 1 (2%) patient, and low cardiac output necessitating an intra-aortic balloon pump in 1 (2%) patient. One patient had a graft-esophageal fistula after the ascending aorta, total arch, and descending aortic replacement, which was successfully treated with direct repair of the esophageal perforation with wrapping by pedicled intercostal muscle and debridement and antibiotic irrigation, followed by omental wrapping of the graft. This patient is now in good condition and is free from infection 10 months after the operation.

Extracorporeal circulation data. Mean CPB time was 173.5 ± 47.1 minutes, mean aortic crossclamp time was 100.2 ± 33.9 minutes, mean systemic circulatory arrest time was 39.2 ± 14.6 minutes, and mean SCP time was 78.1 ± 16.5 minutes. Fig 2 shows patient distribution according to SCP time. Twenty-four (48%) patients had an SCP time of longer than 80 minutes. No

Fig 3. Medium-term survival of patients undergoing total arch replacement for atherosclerotic aneurysm.

significant correlation was found between SCP time and temporary and permanent neurologic dysfunction.

Medium-term survival. Fig 3 shows the actuarial survival curves estimated by the Kaplan-Meier method. The 24-month survival, including in-hospital death, was 92% (95% CI, 84%-100%).

During a mean follow-up period of 15.3 months (range, 1-36 months), there were 2 deaths. One patient died of rupture of the descending aorta after an acute type B dissection 3.6 months after the operation. The other died of a cerebrovascular accident 4.7 months after the operation.

Discussion

Reducing the incidence of postoperative stroke is a formidable challenge in the field of cardiac surgery. Despite recent improvements in operative techniques and preoperative and intraoperative management, the stroke rate after CABG has remained relatively unaltered. The reported incidence of stroke after CABG is in the range of 1% to 6%.⁸⁻¹¹ Atherosclerosis of the ascending aorta, carotid arterial disease, and older age have been identified as risk factors for postoperative stroke. The 1997 Society of Thoracic Surgeons National Cardiac Surgery Database reported a postoperative permanent stroke rate of 1.65%, transient stroke rate of 0.74%, delirium rate of 2.62%, and rate of continuous coma for more than 24 hours of 0.43% after CABG.¹² Stroke after CABG obviously increases the in-hospital mortality and adversely influences the length of hospital stay. Therefore, a thorough evaluation of the preoperative risk factors and appropriate intraoperative measures to reduce cerebral

embolic and ischemic events are mandated. Postoperative stroke generally has a higher incidence after aortic arch operations for atherosclerotic aneurysm than after CABG. Because surgery for atherosclerotic arch aneurysm poses some additional risk of cerebral embolism and requires cerebral protection against ischemia during aortic arch exclusion, the incidence of postoperative neurologic dysfunction after this type of operation is likely to be even higher.

Some recent reports indicate that 30-day or in-hospital mortality rates after aortic arch operations for atherosclerotic aneurysm range from 6.3% to 20%, and the stroke rates for this type of operation vary from 4.0% to 11%.^{1-4,13,14} Compared with these results, the 2% in-hospital mortality, 4% temporary neurologic dysfunction, and 4% permanent neurologic dysfunction that we had in our series are satisfactory outcomes.

Generally speaking, antegrade SCP as the brain protection method has been instrumental for us in improving the outcomes of aortic operations, and we have already reported its unique advantages.^{5-7,15} Although postoperative stroke in aortic arch operations usually results from cerebral emboli and has nothing to do with the cerebral protection method,^{1,2} our 4% temporary neurologic dysfunction is markedly lower than the 20% to 25% in other series in which profound hypothermia and circulatory arrest with or without retrograde cerebral perfusion have been used.^{2,16} In addition to that, although operating for atherosclerotic arch aneurysms, we adopt the following special measures to avoid cerebral embolic events: if the aneurysm is located in the distal aorta

or if there are severe atherosclerotic lesions, we prefer to cannulate the ascending aorta for instituting CPB. Before cannulating the ascending aorta for CPB, epiaortic 2-dimensional ultrasonography is performed to determine an atherosclerotic plaque-free site for the cannulation. This contributes to reduced cerebral embolism from the ascending aorta. Furthermore, to reduce embolic phenomena from the distal aorta, antegrade perfusion through the fourth limb of the arch graft is initiated after the distal anastomosis is completed. The fact that we changed the arterial cannulation site during the course of this study is significant. Of the earlier 16 patients of this series who had femoral artery cannulation, 1 patient had embolic cerebral stroke. Then we switched to ascending aortic cannulation. However, the issue of the most suitable cannulation site for patients with atherosclerotic arch aneurysm continues to be investigated. The right subclavian artery or axillary artery have come up as possible options.¹⁷ Fortunately, in the 34 patients of this series in whom we performed ascending aortic cannulation, the ascending aorta was found to be a good cannulation site by means of epiaortic ultrasonographic scanning. However, if the ascending aorta would be unsuitable, our next choice would be the right axillary artery. In fact, we have already used axillary artery cannulation at our institution and have obtained good results.

One of the key points about SCP is the arch vessel cannulation. We believe that our newly developed perfusion cannula and our recently refined cannulation technique made it easier for us to avoid the cannulation-related complications, such as cerebral embolization of dislodged atherosclerotic debris or air. Because atherosclerotic lesions are commonly located at the origins of the arch vessels, it is very important to transect them at places where they are free from such lesions to avoid dislodgment of atherosclerotic debris. Again, while cannulating, we meticulously evacuate air from the cannulas to reduce the incidence of air embolism.

Our newly developed perfusion cannula is very convenient in use because it can be bent at right angles with the help of its flexible metallic support and also allows pressure monitoring.

It has been recognized that atherosclerosis of the ascending aorta is a major cause of stroke after CABG¹⁸⁻²⁰ and also after aortic arch operations.² Therefore, our philosophy about the extent of aortic replacement in this type of operation is that all the potential sources of cerebral embolism must be radically removed, and that is why we also replace the ascending and the descending aorta in addition to performing the

arch replacement. In these operations the site of aortic cannulation and that for infusion of cardioplegic solution are also resected because they are potential sources of cerebral emboli.²⁰ We have extensively used the separated graft technique by using the aortic arch branched graft for atherosclerotic arch aneurysm. This technique has several advantages when compared with en bloc repair, in which the arch vessels are anastomosed to the side hole of the arch graft in an island fashion. The use of a separated graft technique automatically excludes the atherosclerotic lesions at the origins of the arch vessels and also allows us to easily control bleeding from the arch vessel anastomosis. These can reduce the incidence of postoperative neurologic dysfunction.

The presence of carotid arterial disease is another risk factor of stroke after cardiac surgery. We routinely perform preoperative cerebral 4-vessel angiography and cerebral computed tomographic scanning to rule out carotid arterial disease, and we have not encountered this important lesion in our series.

A history of cerebrovascular disease was also a significant risk factor of stroke in our series, which is consistent with other studies on CABG^{9,11} and aortic arch operations with profound hypothermia and circulatory arrest with or without retrograde cerebral perfusion.^{1,2} A history of cerebrovascular disease suggests existing pathologic cerebrovascular conditions, such as impaired cerebral blood flow and autoregulation or inadequate collateral vessels, which may predispose patients to having a stroke after cardiovascular operations. Therefore, for patients with old cerebrovascular disease, further improvement in brain protection methods will be necessary.

In summary, surgery for atherosclerotic arch aneurysm carries a high risk of perioperative cerebral embolism and therefore generally has a higher postoperative stroke rate. However, our refined surgical technique for this kind of operation allowed us to significantly reduce mortality and postoperative neurologic dysfunction.

Received for publication Aug 2, 2000; accepted for publication Oct 20, 2000.

Address for reprints: Teruhisa Kazui, MD, First Department of Surgery, Hamamatsu University School of Medicine, 3600 HANDA-CHO, Hamamatsu, Japan, 431-3192 (E-mail:surg1ss@hama-med.ac.jp).

REFERENCES

1. Svensson L, Crawford ES, Hesse KR, Coselli JS, Raskin S, Shenaz SA, et al. Deep hypothermia circulatory arrest. Determinants of stroke and early mortality in 656 patients. *J Thorac Cardiovasc Surg* 1993;106:19-31.

2. Ergin MA, Galla JD, Lansman SL, Quintana C, Bodian C, Griepp RB. Hypothermic circulatory arrest in operations on the thoracic aorta: determinants of operative mortality and neurologic outcome. *J Thorac Cardiovasc Surg* 1994;107:788-99.
3. Okita Y, Ando M, Minatoya K, Kitamura S, Takamoto S, Nakajima N. Predictive factors for mortality and cerebral complications in atherosclerotic aneurysm of the aortic arch. *Ann Thorac Surg* 1999;67:72-8.
4. Bachet J, Guilmet D, Goudot B, Dreyfus GD, Delentdecker P, Brodaty D, et al. Antegrade cerebral perfusion with cold blood: a 13-year experience. *Ann Thorac Surg* 1999;67:1874-8.
5. Kazui T, Washiyama N, Bashar AHM, Terada H, Yamashita K, Takinami M, et al. Total arch replacement using aortic arch branched graft with the aid of antegrade selective cerebral perfusion. *Ann Thorac Surg* 2000;70:3-8.
6. Kazui T, Inoue N, Yamada O, Komatsu S. Selective cerebral perfusion during operation for aneurysms of the aortic arch: a reassessment. *Ann Thorac Surg* 1992;53:109-14.
7. Kazui T, Kimura N, Yamada O, Komatsu S. Surgical outcome of aortic arch aneurysms using selective cerebral perfusion. *Ann Thorac Surg* 1994;57:904-11.
8. Gardner TJ, Horneffer PJ, Manolio TA. Stroke following coronary artery bypass grafting: a ten-year study. *Ann Thorac Surg* 1985;40:574-81.
9. Wareing TH, Davila-Roman VG, Daily BB, Murphy S, Schechtman KB, Barzilai B, et al. Strategy for the reduction of stroke incidence in cardiac surgical patients. *Ann Thorac Surg* 1993;55:1400-8.
10. Roach GW, Kanchuger M, Mangano CM, Newman M, Nussmeier N, Wolman R, et al. Adverse cerebral outcomes after coronary bypass surgery. *N Engl J Med* 1996;335:1857-63.
11. John R, Choudhri AF, Weinberg AD, Ting W, Rose EA, Smith CR, et al. Multicenter review of preoperative risk factors for stroke after coronary artery bypass grafting. *Ann Thorac Surg* 2000;69:30-6.
12. STS National Database 1997. Available at: <http://www.sts.org/doc/3035>. Accessed on July 21, 2000.
13. Borst HG, Bühner B, Jurman M. Tactics and techniques of aortic arch replacement. *J Card Surg* 1994;9:538-47.
14. Coselli JS, Buket S, Djukanovic B. Aortic arch operation: current treatment and results. *Ann Thorac Surg* 1995;59:19-7.
15. Kazui T, Washiyama N, Bashar AHM, Terada H, Yamashita K, Takinami M, et al. Extended total arch replacement for acute type A aortic dissection: experience with 70 patients. *J Thorac Cardiovasc Surg* 2000;119:558-65.
16. Okita Y, Takamoto S, Morota T, Matsukawa R, Kawashima Y. Mortality and cerebral outcome in patients who underwent aortic arch operations using deep hypothermic circulatory arrest with retrograde cerebral perfusion: no relation of early death, stroke, and delirium to the duration of circulatory arrest. *J Thorac Cardiovasc Surg* 1998;115:129-38.
17. Sabik J, Lytle W, McCarthy M, Cosgrove D. Axillary artery: an alternative site of arterial cannulation for patients with extensive aortic and peripheral vascular disease. *J Thorac Cardiovasc Surg* 1995;109:885-91.
18. Mill NL, Everson CT. Atherosclerosis of the ascending aorta and coronary artery bypass: pathology, clinical correlates, and operative management. *J Thorac Cardiovasc Surg* 1991;102:546-53.
19. Blauth CL, Cosgrove DM, Webb BW, Ratiff NB, Boylan M, Piedmonte MR, et al. Atheroembolism ascending aorta: an emerging problem in cardiac surgery. *J Thorac Cardiovasc Surg* 1992;103:1104-12.
20. Ura M, Sakata K, Nakayama Y, Miyamoto TA, Goto T. Extracorporeal circulation before and after ultrasonographic evaluation of the ascending aorta. *Ann Thorac Surg* 1999;67:478-83.