Original Article

A Retrospective Comparative Study of Deep Hypothermic Circulatory Arrest, Retrograde, and Antegrade Cerebral Perfusion in Aortic Arch Surgery

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Objective: Despite theoretical advantages of antegrade (ACP) and retrograde cerebral perfusion (RCP) in addition to deep hypothermic arrest (DHA) in aortic arch surgery, there is still controversy about the best method of cerebral protection. We reviewed our experience with neurological outcome after aortic arch repair over the last five years.

Methods: Sixty-two patients undergoing aortic arch repair were reviewed. Five patients (8.1%) had Marfan's syndrome, 11 (17.7%) had previous cardiac operations, and 13 (21.0%) also received coronary bypass grafting (CABG). The extent of arch replacement was proximal level in 40 (64.5%), distal level in 18 (29.0%), and total in 13 (21.0%). The method of cerebral protection was DHA alone in 14 patients, DHA with RCP in 23, and DHA with ACP in 25. Pre-, intra-, and postoperative variables in the three categories of cerebral protection were compared. Specifically, the independent predictors of mortality, stroke, and temporary neurological dysfunction (TND) were examined.

Results: Overall hospital mortality was 5 (8.0%). Stroke occurred in 4 patients (6.4%), and TND in 5 (8.0%). There were no significant differences among the groups in mortality or neurological dysfunction. Total brain exclusion time (TBET) was significantly longer in ACP (DHA, 25.2±12.0 min; ACP, 61.8±44.1 min; RCP, 36.4±20.5 min; p=0.023). Multivariate analysis showed a trend for TBET of longer than 90 minutes as a predictor of stroke (p=0.06; odds ratio, 7.9). The actuarial survival rate was 88.7% at five years (DHA, 85.7%; ACP, 80.0%; RCP, 100%; no significant difference).

Conclusions: Despite more complicated arch repairs requiring a significantly longer cerebral exclusion time which were performed in the group receiving ACP, there was no significant increase in stroke or death rates. Increasing confidence in the ability of ACP has led us to perform the most appropriate arch repair without compromising the extent of replacement for fear of exceeding the "safe" period of circulatory arrest. (Ann Thorac Cardiovasc Surg 2003; 9: 174–9)

Key words: aortic surgery, circulatory arrest, cerebral protection

Introduction

Although there have been major advances in cerebral protection during aortic arch surgery, there remains a significant incidence of transient and permanent neurological dysfunction. Several ancillary measures such as antegrade (ACP) and retrograde cerebral perfusion (RCP) in addition to deep hypothermic arrest (DHA) have been advocated.[1,2] Despite the theoretical advantages of these adjuncts, there is still controversy about the best method of cerebral protection.[1-4] We reviewed our experience with neurological outcome after aortic arch repair with particular reference to the method of protection used over

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Table 1. Patient profiles

	DHA (n=14)	ACP (n=25)	RCP (n=23)	P value
Age	64.2±9.7	66.5±12.8	62.7±11.1	0.5382
Sex	M12, F 4	M 21, F 2	M 16, F 7	0.3691
Marfan	0	4 (16.0%)	1 (4.3%)	0.1511
Dissection	6 (42.9%)	9 (36.0%)	17 (73.9%)	0.0214
Emergency	4 (28.6%)	6 (24.0%)	13 (56.5%)	0.05
CVD	1 (7.1%)	6 (24.0%)	2 (8.7%)	0.2215
CPD	3 (21.4%)	6 (24.0%)	3 (13.0%)	0.6154
PVD	2 (14.3%)	4 (16.0%)	2 (8.7%)	0.741
LVH	7 (50.0%)	12 (48.0%)	14 (60.9%)	0.6464
Rupture	1 (7.1%)	3 (12.0%)	4 (17.4%)	0.6558
S-Cr (mmol/L)	117.9±51.0	105.3±31.3	107.6±15.7	0.6375
Tamponade	1 (7.1%)	1 (4.0%)	4 (17.4%)	0.2738
IHD	6 (42.9%)	7 (28.0%)	8 (34.8%)	0.6383
Shock	1 (7.1%)	2 (8.0%)	4 (17.4%)	0.5052
Second operation	5 (35.7%)	6 (24.0%)	4 (17.4%)	0.4507

DHA, deep hypothermic arrest; ACP, antegrade cerebral perfusion; RCP, retrograde cerebral perfusion; CVD, cerebrovascular disease; CPD, chronic pulmonary disease; PVD, peripheral vascular disease; LVH, left ventricular hypertrophy; S-Cr, serum creatinine; IHD, ischemic heart disease.

the last five years.

Patients and Methods

Sixty-two patients with aortic arch aneurysm or dissection were operated on between January 1996 and December 2000 at our institution. Patient data is summarized in Table 1. Mean age was 64.6±11.4 years (41-82). Five patients (8.1%) had Marfan's syndrome, 11 (17.7%) had previous cardiac operations, and 32 (51.6%) suffered from aortic dissection. Twenty-three patients (37.1%) had emergency operation. Thirteen (21.0%) had concomitant coronary bypass grafting (CABG). Descending or thoracoabdominal aortic repair was performed in 22 (35.5%) patients. The extent of arch replacement was proximal in 40 (64.5%), distal in 18 (29.0%), and total in 13 (21.0%) patients. Aortic root replacement was concomitantly performed in 15 (24.2%) patients.

Cerebral protection methods

The right innominate artery, left common carotid artery, and left subclavian artery (SCA) were perfused by using an occluding balloon catheter. ACP was performed by attaching an end-to-side graft to the right SCA and occluding the right innominate artery by using a balloon catheter in a few cases. Radial artery pressure were maintained at 40 to 60 mmHg. RCP was performed by a retrograde coronary sinus type perfusing catheter inserted into the superior vena cava (SVC) with flows of 200 to 300 ml/min while monitoring the perfusion pressure between 20 and 25 mmHg. The patient's head was packed in ice at the start of cooling.

Brain complications

Any new lesion detected by CT or persistent focal neurologic deficit were defined as stroke. Temporary neurological dysfunction (TND) was defined as mild intellectual disturbance, confusion, disorientation, or memory disturbance.

The method of cerebral protection was DHA alone in 14 patients, DHA with RCP in 23, and DHA with ACP in 25. The frequency of pre-, intra-, postoperative variables in the three categories of cerebral protection was tested using the chi-square and ANOVA. Specifically, the independent predictors of mortality and stroke and TND were identified using the logistic regression analysis. Follow up information was obtained on all patients. Patients or their referring cardiologists or local doctors were contacted by telephone or by mailed questionnaire. Actuarial survival rate was estimated with the Kaplan-Meier method. P values of less than 0.05 were regarded as a statistically significant difference.

Results

Preoperative patient profiles are shown in Table 1. There

Table 2. Perioerative details

	DHA	ACP	RCP	P value
CABG (case)	3 (21.4%)	2 (8%)	8 (34.8%)	0.0747
Extent of replace (case)	De 6, Tab 2	De 9, Tab 2	De 3, Tab 0	0.0525
Minimum temp (min)	19.4±1.5	19.2±1.6	19.4±0.9	0.8296
DHAT (min)	25.2±12.4	11.4±9.6	37.4±19.2	
ACPT (min)		49.6±0.5		
RCPT (min)			30.6±19.0	
TBET (min)	25.2±12.0	61.8±44.1	36.4±20.5	0.023
Cardiac exclusion (min)	81.0±67.9	137.6±82.1	105.8±32.7	0.2789
CPBT (min)	196.0±60.4	247.8±86.4	193.5±34.9	0.0024
Native aortic clamp (case)	8 (57.1%)	18 (72%)	13 (56.5%)	0.5463
Arch replacement (case)	P 6, D 8, T 1	P 11, D 8, T 6	P 15, D 2, T 6	0.0308

DHA, deep hypothermic arrest; ACP, antegrade cerebral perfusion; RCP, retrograde cerebral perfusion; De, descending aortic replacement; Tab, thoracoabdominal aortic replacement; DHAT, DHA time; ACPT, ACP time; RCPT, RCP time; TBET, total brain exclusion time; CBPT, cardiopulmonary bypass time; P, proximal; D, distal; T, total.

Table 3. Postoperative details

	DHA	ACP	RCP	P value
Intubation (hr)	13.5±4.5	17.6±10.5	29.1±26.8	0.0719
ICU stay (day)	2.5±1.5	8.6±12.8	3.0±1.4	0.0609
HP stay (day)	9.5±3.8	18.9±20.2	14.3±15.2	0.2838
Mech support (case)	1 (7.1%)	0	3 (13.0%)	0.1835
Inotropes (case)	8 (57.1%)	7 (28%)	8 (34.8%)	0.1873
Reexploration (case)	2 (14.3%)	3 (12%)	5 (21.7%)	0.6566
Tracheostomy (case)	0	6 (24%)	0	0.0083
Acute renal failure (case)	2 (14.3%)	7 (28%)	3 (13.0%)	0.3891
Af (case)	0	4 (16%)	1 (4.3%)	0.1623
Stroke (case)	0	3 (12%)	1 (4.3%)	0.316
TND (case)	1 (7.1%)	4 (16%)	0	0.13
HP death (case)	1 (7.1%)	4 (16%)	0	0.1251

DHA, deep hypothermic arrest; ACP, antegrade cerebral perfusion; RCP, retrograde cerebral perfusion; ICU, intensive care unit; HP, hospital; Mech support, mechanical circulatory support; Af, atrial fibrillation; TND, temporary neurological dysfunction.

were no significant differences in preoperative demographics. Aortic dissection and emergency surgery were most common in the RCP group (p=0.02, 0.05). Descending or thoracoabdominal aortic repair were performed most often in the ACP group (p=0.05). Minimum nasopharyngeal temperature was approximately 19°C and it was quite similar among the groups. The mean total circulatory arrest time was 25.2±12.4 min in the DHA group, 11.4±9.6 min in the ACP group, and 37.4±19.2 min (include RCP time) in the RCP group, respectively (Table 2). TBET, which was defined as the duration between the start of DHA and restart of brain circulation with normal bypass, was significantly longer in the ACP group than in the other groups (p=0.003, Table 2). Cardiopulmonary bypass (CPB) time was also significantly longer in the ACP group. Overall hospital mortality was five (8.1%) patients. Stroke occurred in four (6.0%) patients, and TND in five (8.0%) patients. There was no significant difference among the three methods of cerebral protection in mortality or neurological dysfunction. The incidence of tracheostomy was significantly higher in the ACP group (p=0.0083, Table 3). Multivariate logistic regression analysis revealed the presence of peripheral vascular disease (PVD) as the only independent predictor of TND (p=0.0258; odds ratio, 37.2; Table 4). There was also a trend for TBET of longer than 90 minutes as a predictor

Table 4. Risk analysis

Hospital mortality	Univariate	Multivariate	Odds ratio
TND	0.026	0.5684	2.5
Acute renal impairment	0.0002	0.6371	20.5
Tracheostomy	0.0251	0.0906	2.3
TND			
PVD	0.0104	0.0258	37.2
Rupture	0.0104	0.2309	7.5
Inotropes	0.05	0.2069	6.8
Age>70 years	0.06	0.1495	11.7
Stroke			
Reoperation	0.0035	0.1045	10
TBET>90 min	0.0297	0.0677	7.9

TND, temporary neurological dysfunction; PVD, peripheral vascular disease; TBET, total brain exclusion time.

of stroke (p=0.0677; odds ratio, 7.9; Table 4). Although univariate analysis picked up TND, tracheostomy, and acute renal impairment (creatinine > 0.2 mmol/L) as risk factors of mortality, multivariate analysis failed to detect any significant risk factors of mortality (Table 4). Mean follow up duration was 40.1 months ranging from 1 to 70 months. The total actuarial survival rate was 88.7% at five years (DHA, 85.7%; ACP, 80.0%; RCP, 100%; Fig. 1).

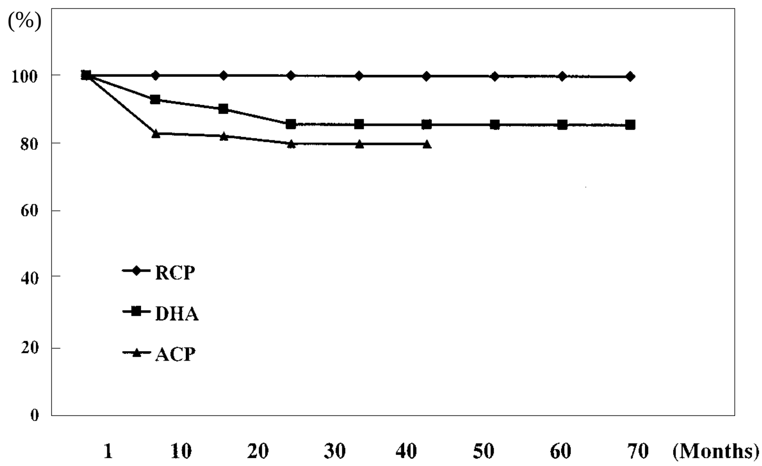

Fig. 1. Actuarial survival rate. Mean follow up duration was 40.1 months ranging from 1 to 70 months. The total actuarial survival rate was 88.7% at five years (DHA, 85.7%; ACP, 80.0%; RCP, 100%; no significant difference).

Discussion

Neurological complications are a frequent cause of death or disability after aortic arch operations. Although recent progress in cerebral protection during aortic surgery has been achieved, significant incidence of permanent or transient neurological disorders have remained a major unsolved problem. Several methods of brain protection such as ACP and RCP have been published.[1-5] However, the comparative results are still controversial. Ueda and colleagues firstly reported the effectiveness of retrograde cerebral perfusion.[6] They outline that the advantages of RCP include uniform brain cooling, de-airing of the arch vessels, the capability of flushing of cerebral emboli, flushing of toxic metabolites that accumulate during DHA, and provision of oxygen and substrates.[2] Coselli et al. reported that the mortality (7.9%) and stroke (2.4%) rates of the patients undergoing aortic surgery with DHA and RCP were significantly lower than those with DHA alone.[7] Safi et al. also demonstrated that RCP showed a protective effect against stroke.[8] However, the physiologic advantage of retrograde cerebral perfusion has not been clarified. Svensson et al. report that the brain is incompletely perfused by the RCP method.[4] Although RCP can extend the safety duration of DHA, it is considered to be limited to up to 80 minutes.[3] On the other hand, it has been reported that the incidence of TND was significantly higher in the patients with RCP than with ACP.[9] Although some uptake of oxygen during retrograde flow clearly occurs, most of the efforts to document significant improvement in cerebral metabolic function as a result of nutritive flow during RCP have failed.[10] In this study, multivariate regression detected the PVD as the only significant predictor of TND. Okita and colleagues demonstrated that risks for TND were an age older than 70 years and atherosclerotic aneurysm.[3] It has been reported that the use of supplemental cerebral perfusion did not appear to change the incidence of TND.[5] On the other hand, Hagl et al. reported the method of cerebral protection did not influence the occurrence of stroke, but ACP resulted in a significant reduction in incidence on TND.[11] We think the cause of TND might be associated with not only the methods of cerebral protection but also patients' individual factors such as age, severity of atherosclerosis, and so on.

In the present study, there was one patient complicated by stroke and no patient had TND in the RCP group. The average RCP + DHA duration of this series was 37.4±19.2 minutes, which was much shorter than the critical limit of RCP duration mentioned above. These results suggested that the medium duration of RCP was quite safe for aortic arch operation with DHA. Meanwhile, stroke occurred in three patients (12.0%) and TND in four patients (16.0%) with ACP in our patients. In the present study, the rate of extended descending to thoracoabdominal aortic repair concomitantly with arch replacement was significantly higher in the patients with ACP. We normally employ ACP for patients who need longer cerebral protection, because ACP can provide the luxury of time, allowing for appropriate repair of complicated arch aneurysms. However, ACP also has the more serious potential disadvantage of requiring manupulation of cerebral vessels, with the risk of dislodging atherosclerotic debris.[1]

A recent report indicated that the majority of permanent neurologic injuries were due to strokes resulting from embolic phenomena and were not directly related to the method of cerebral protection used.[4,12] In this study, comparative demographic variables show no significant differences between the groups with different cerebral protection methods. However, the incidence of dissection and emergencies were more frequently seen in the RCP group. Because of the frequent indication of a lot of clotting around arch vessels in the patients with type A aortic dissection, ACP was considered slightly risky in the case of a clot dislodging to the brain. A proximal arch repair was commonly required in such an emergency case. Therefore, CPB and TBET were significantly shorter in the RCP group than in the ACP group. This bias is considered one of the weaknesses of this study and also, the number of patients in each group was not large. Furthermore, patients undergoing ACP had significantly longer TBET than patients with DHA or RCP. In addition, the rate of concomitant descending and thoracoabdominal repair was significantly higher in the ACP group, in which there is a higher risk of stroke as well as age and severe atheromatous disease of the aorta.[5] In our series, even though the majority of the patients with ACP had more complicated arch repair and needed a longer duration of TBET, there were no differences in the incidence of stroke and TND compared to the patients with DHA or RCP. However, multivariate regression detected longer TBET as a relatively close significant predictor of stroke. Hagl and colleagues reported that longer TBET was associated with a greater risk of permanent stroke.[11] They also demonstrated that there was no influence of perfusion technique on the incidence of stroke in this group with prolonged TBET.[11] Kazui et al. reported an incident of stroke, which occurred in a patient with a duration of SCP longer than 90 minutes in a series of 100 patients.[13] Such a time limit has to be taken into consideration, especially when extensive operations involving the descending aorta in patients with underlying atheromatous lesions predisposing to stroke were required.

Conclusions

Aortic arch replacement can be achieved with acceptable mortality and neurological dysfunction. Despite more complicated arch repairs, requiring significantly longer cerebral exclusion time, which were performed in the group receiving ACP, there was no significant increase in stroke or death rates. Increasing confidence in the ability of ACP to provide nutritive cerebral blood flow during brain exclusion, has led us to perform the most appropriate arch repair without compromising the extent of replacement for fear of exceeding the "safe" period of circulatory arrest. However, a TBET of longer than 90 minutes has to be taken into consideration for the risk of stroke.

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