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RETROGRADE CEREBRAL PERFUSION WITH HYPOTHERMIC CIRCULATORY ARREST IN AORTIC ARCH SURGERY: OPERATIVE AND LONG-TERM RESULTS

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Abstract

Methods: Clinical data were retrospectively collected for 207 consecutive patients who underwent aortic arch surgery using continuous retrograde cerebral perfusion (CRCP) and hypothermic circulatory arrest (HCA) at Tenri Hospital (138 patients) from 1988 to 1999, and at Nagoya University Hospital (69 patients) from 1990 to 2000. One hundred and 3 patients (50%) were operated upon for aortic dissection, and 104 patients (50%) for atherosclerotic aneurysm.

Results: Hospital mortality was 12% (25 patients). HCA times were 44±20 minutes. Cardiopulmonary bypass time longer than 6 hours, low cardiac output syndrome, respiratory failure, and central nervous system (CNS) dysfunction contributed to.hospital deaths. Late mortality was 16% (34 patients). The predictors of late deaths were age (>70 years), total arch replacement, HCA time >60 min., non-dissecting aneurysm, and postoperative CNS injury.

Conclusions: Operative results of aortic arch surgery using CRCP was generally satisfactory. However, the long-term results of total arch replacement for patients older than 70 years, non-dissecting aneurysm (particularly ruptured), and postoperative CNS injury were poor. Although prolonged duration of HCA may contribute to these poor results, other factors such as emergent surgery, late death due to aging, and systemic atherosclerosis are also considered to be risk factors.

Key Words: aortic arch surgery, hypothermic circulatory arrest, retrograde cerebral perfusion, brain protection

Introduction

Surgery on the aortic arch requires systemic organ protection. The brain in particular is the most vulnerable organ during the interval in which normal circulation is interrupted. As well as preventing ischemic injury to the brain during repair of the aortic arch, the prevention of an embolization of the thrombus or of atheromatous debris escaping into cerebral circulation immediately following a graft replacement are important.

Hypothermic circulatory arrest (HCA) has been widely utilized for aortic arch surgery.[1)-8)] It can be used by itself in most operations where the duration is not expected to exceed 45 min.[2)-4)] The clinical application of continuous retrograde cerebral perfusion (CRCP or RCP) combined with HCA for aortic arch surgery was first shown in a substantial series of reports

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by us starting in 1988.[9)-11)] Many reports supported the efficacy of CRCP and identified a reduction in early mortality and morbidity.[12-22)]

In this article, our clinical results of aortic arch surgery using HCA and CRCP are described, and are reviewed based on analysis of risk factors.

Patients and Methods

Patients

Between March 1988 and December 1999, 138 consecutive patients underwent partial or total aortic arch replacement using CRCP and HCA at Tenri Hospital, and 69 patients underwent aortic arch surgery using the same adjunct at Nagoya University Hospital from December 1990 to December 2000. Ages ranged from 37 to 88 years, with a mean age of 66 years. Eighty patients (39%) were older than 70. One hundred four patients (50%) were operated upon for thoracic atherosclerotic aneurysm (TAA) and 103 patients (50%) for dissecting aortic aneurysm (DAA). Ninety of these patients (43%) underwent emergency operations because of a rupture of TAA or acute type A dissection (Table 1).

Mode of aortic arch surgery

Replacement of the ascending aorta and hemi-arch replacement were carried out in 78 patients. This surgery included composite valve graft replacement or resuspension of the aortic valve. Total aortic arch replacement was done in 55 patients, distal arch replacement in 58 patients, and descending aorta replacement in 21 (Table 2). During the aortic arch replacement, HCA and CRCP were utilized for brain protection in all patients. The precise technique has already been described.[9)-12)]

Table 1 Demographic data of patients

Tenri Hospital	(1986-1999): 138 patients	(TAA 66, DAA 72)
Nagoya University	(1990-2000): 69 patients	(TAA 38, DAA 31)

TAA	
AAE	5
ascending aorta	3
arch	88
descending aorta	3
total	104

DAA	
DeBakey I	66
DeBakey II	16
DeBakey III	21
total	103

	TAA	DAA	all
male/female	78:26	50:53	128:79
age (yr.)	69±9	63±10	66±10
age >70 yr.	54 (52%)	26 (25%)	80 (39%)
Emergency	21 (20%)	69 (67%)	90 (43%)

TAA: thoracic atherosclerotic aneurysm, DAA: dissecting aortic aneurysm, AAE: annuloaortic ectasia

Statistical analysis

To examine factors affecting postoperative hospital and late deaths, the following variables were analyzed by univariate and multivariate unconditional logistic analysis: age, urgency of surgery, duration of cardiopulmonary bypass time, operation time, HCA time, mode of surgery performed, and neurological complications. Survival rates were analyzed by the Kaplan-Meier method. A p value less than 0.05 was considered statistically significant.

Results

Cardiopulmonary bypass (CPB) times were 213±104 min. and HCA times were 44±20 min. (Table 2). Hospital mortality was 12% (25 patients) including operative deaths 7% (15 patients). Late mortality was 16% (34 patients) (Table 3). Causes of hospital and late deaths are listed in Tables 4 and 5.

CPB time longer than 6 hours, low cardiac output syndrome, respiratory failure, and central nervous system (CNS) dysfunction contributed to the hospital deaths of TAA patients. In patients with DAA, CPB time longer than 6 hours and respiratory failure were statistically significant predictors of hospital death (Table 6). Predictors of late death of TAA patients were emergency surgery, patient's age above 70 years, total arch replacement, HCA longer than 60

Table 2 Operative data

	TAA	DAA	all
CPB time (min.)	218±106	209±102	213±104
CPB > 6 hr	6 (6%)	7 (7%)	13 (6%)
Operation (min.)	457±154	455±244	456±199
Operation > 12 hr	6 (6%)	8 (8%)	14 (7%)
HCA (min.)	45±19	43±22	44±20
HCA > 60 min.	24 (24%)	17 (17%)	41 (20%)
Aorta replaced			
ascending aorta	4	23	27
hemi-arch	13	38	51
aortic arch	30	25	55
distal arch	49	9	58
descending aorta	13	8	21

CPB: cardiopulmonary bypass, HCA: hypothermic circulatory arrest

Table 3 Hospital and late death

	TAA	DAA	all
No. of patients	104	103	207
hospital death	12 (11%)	13 (12%)	25 (12%)
operative death	9 (9%)	6 (6%)	15 (7%)
late death	22 (21%)	12 (12%)	34 (16%)
lost follow-up	1 (1%)	4 (4%)	5 (2%)

Table 4 Causes of hospital death

	TAA	DAA	all
operative death	2	1	3
cardiac	3	0	3
CNS injury	4	4	8
respiratory	2	1	3
rupture	1	3	4
infection	1	1	2
GI bleeding	0	1	1
miscellaneous	0	1	1
total	13	12	25

CNS: central nervous system, GI: gastrointestinal

Table 5 Causes of late death

	TAA	DAA	all
sudden death	7	4	11
CVA	6	1	7
neoplasm	3	3	6
cardiac	2	2	4
miscellaneous	2	1	3
unknown	1	2	3
total	21	13	34

CVA: cerebrovascular accident

Table 6 Predictors of hospital death

TAA	uni-variate		multi-variate	
	odds	*p* value	odds	*p* value
Emergency surgery	5.534	0.0089		n.s.
CPB > 6 hr	21.74	0.0011		n.s.
Operation > 12 hr	11.24	0.0075		n.s.
Bleeding	5.050	0.0235		n.s.
LOS	9.523	0.0111		n.s.
CNS injury	4.926	0.0131		n.s.
DAA				
CPB > 6 hr	6.060	0.0330		n.s.
Respiratory	3.817	0.0029		n.s.

min., and postoperative CNS injury (Table 7).

Postoperative survival curves were shown in Figures 1 - 3. There was no significant difference in survival rates between TAA and DAA (Fig. 1). The survival rate of patients after elective surgery for TAA was significantly better than that of emergency surgery patients. Survival

Table 7 Predictors of late death

TAA	uni-variate		multi-variate	
	Odds	*p* value	Odds	*p* value
Emergency surgery	5.747	0.0043		n.s.
Age > 70 yr	6.268	0.0024		n.s.
Total arch replacement	3.326	0.0001	6.732	0.0110
HCA > 60 min.	3.000	0.0416		n.s.
Postoperative CNS injury	10.20	0.0002	16.13	0.0014

DAA
No significant factors

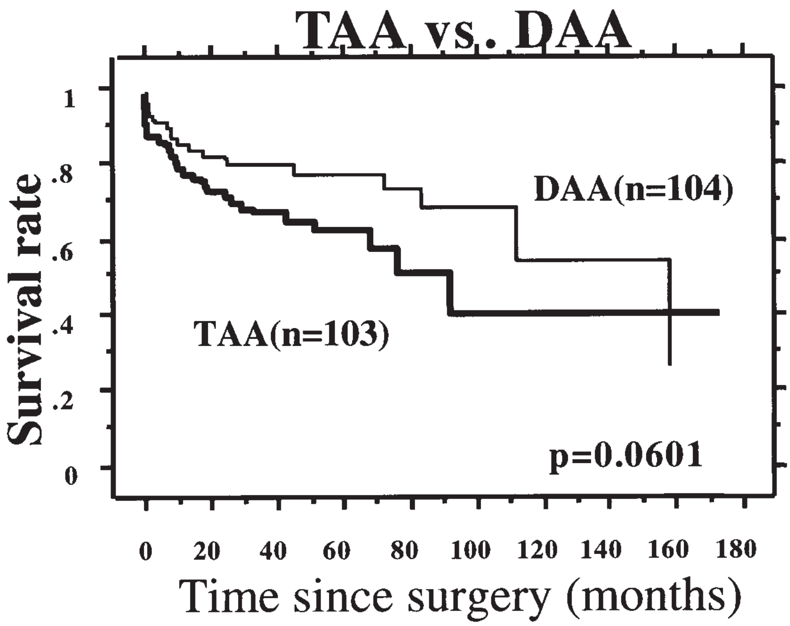

Fig. 1. Overall survival rates in patients with TAA and DAA.
TAA: thoracic atherosclerotic aneurysm, DAA: dissecting aortic aneurysm

rates after total arch replacement in TAA yielded poorer results than other modes of surgery (Fig. 2). The survival rate of patients with CNS injury after surgery for TAA was also poorer than that of those without CNS injury (Fig. 3).

Comment

Cardiopulmonary bypass and HCA have been widely utilized for brain protection during aortic arch surgery. In recent years, the results of surgery for aortic arch aneurysm and aortic dissection using HCA have been generally favorable. However, much longer times are occasionally

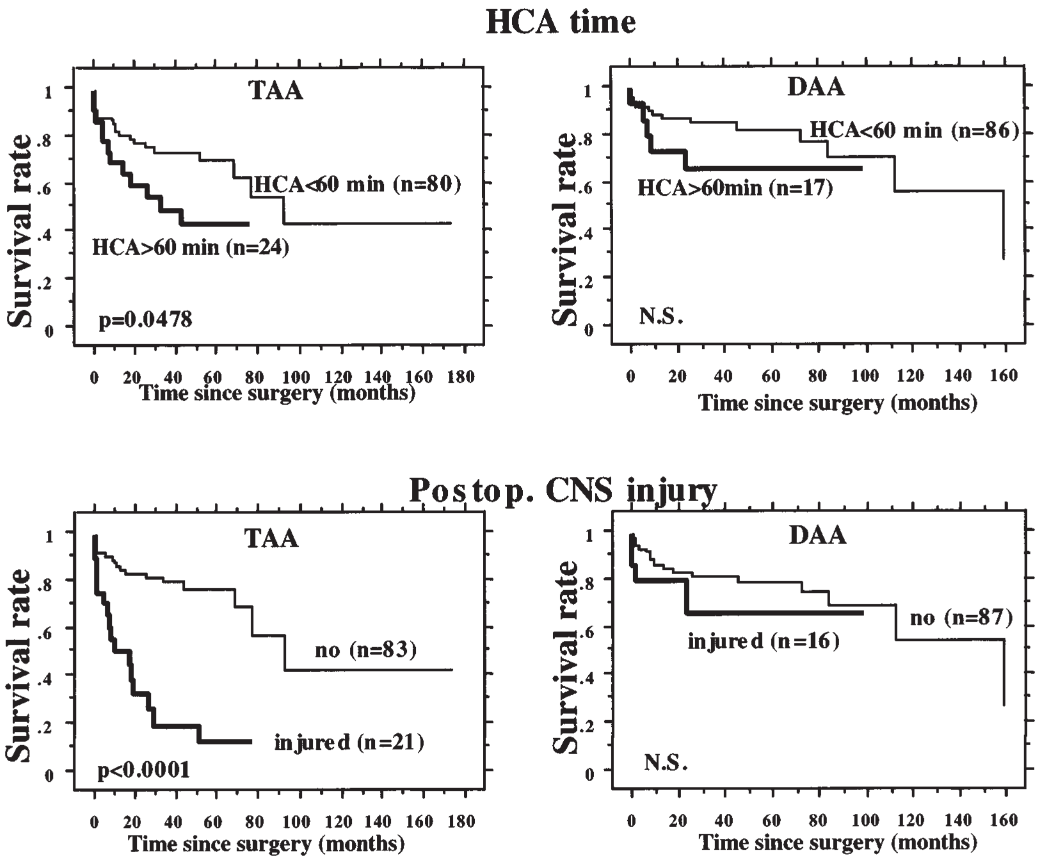

Fig. 2. Survival rates in patients with TAA and DAA: HCA time over 60 min. and less than 60 min., and with or without postoperative CNS injury.

required for the reconstruction of the aortic arch and its branches. Clinical results from extended aortic arch repair clearly indicated that long periods of HCA were associated with a time-dependent neurological morbidity and mortality. In a retrospective analysis of 656 patients, Svensson et al.[4] described an increased incidence of stroke after 40 min. of HCA, and a markedly increased mortality rate after 65 min. of HCA. Recent clinical studies by Ergin et al.[7] indicated that the duration of HCA was not directly correlated with mortality or with permanent neurological injury. They commented that permanent injury was usually focal, and was significantly more frequent in older patients and those with atheroma in the aortic arch or descending aorta at the time of the operation.

RCP entered routine use as an adjunct for prolonged HCA in the 1990s.[9)-22)] RCP was originally used to treat accidental air embolisms during cardiopulmonary bypass by Mills and Ochsner[23] in 1980. In 1982, Lemole and colleagues[24] reported the use of intermittent RCP for the treatment of acute type A dissection using a sutureless graft. RCP into the SVC was used every 20 minutes during HCA. We then extended RCP from intermittent to continuous mode during HCA.[9)-11)] CRCP flow was regulated to maintain a pressure of less than 20 mmHg in the internal jugular vein; this was found to give a satisfactory RCP flow in experimental animal

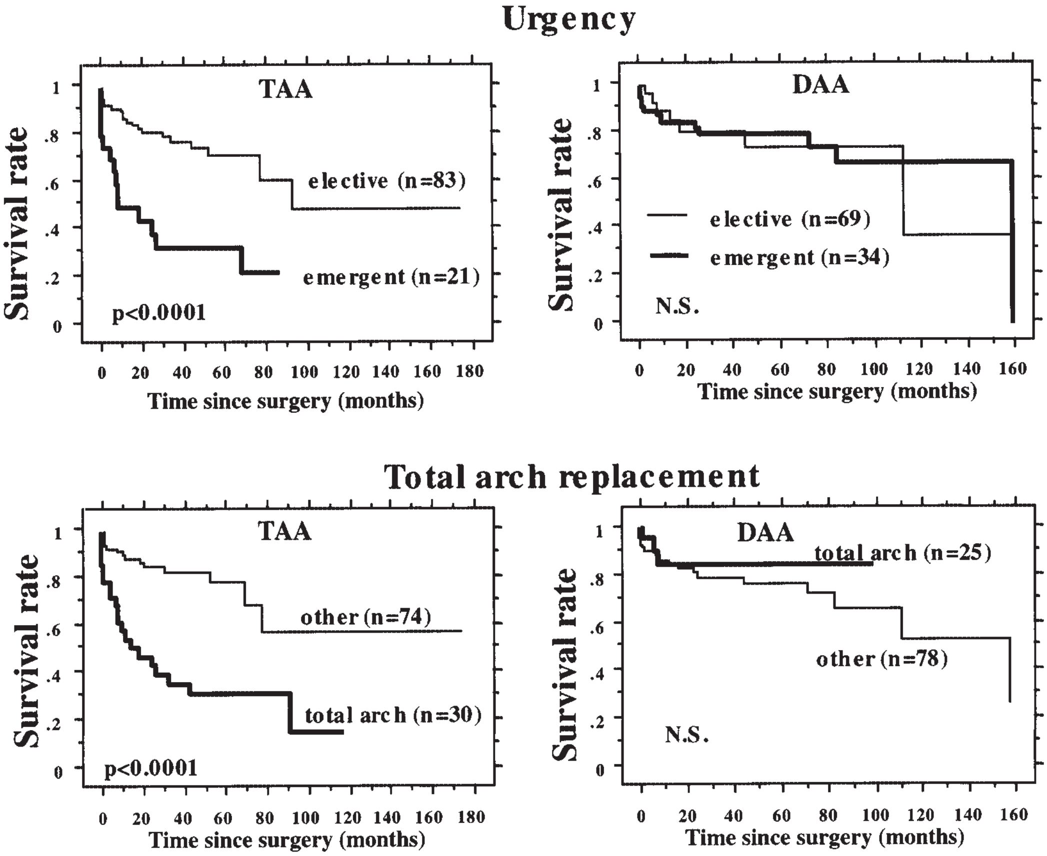

Fig. 3. Survival rates in patients with TAA and DAA: Urgency of surgery and mode of surgery.

models. We have never recommended flow-regulated CRCP but favor pressure-regulated CRCP in order to reduce the risk of edema of the brain with a high jugular vein pressure over 20 mmHg.

There has been sustained support[12)-22)] for the use of CRCP as an adjunct to HCA for surgery of the aortic arch since our report was published in 1990.

Safi and associates[18)] demonstrated that the overall 30-day mortality rate was 6% and the incidence of stroke was 4% in 161 patients who underwent surgery for aneurysms of the ascending aorta and transverse arch using HCA and RCP. The use of RCP demonstrated a protective effect against stroke (3 of 120 patients or 3%) compared with an absence of RCP (4 of 41 patients or 9%; $p < 0.049$). This was most significant in patients over 70 years of age. The pump time was the sole factor found to be associated with an increased risk of stroke and mortality.

Coselli[19)] also described the recent results of aortic arch surgery from July 1987 through March 1997 using HCA with RCP in 305 patients and without RCP in 204 patients. The in-hospital mortality was significantly improved with CRCP at 3.93% (12 patients) compared to those without CRCP at 17.16% (35 patients; p=0.001). The incidence of permanent stroke in patients undergoing RCP was 8/305 (2.62%), and for those without RCP 13/204 (6.37%, p=0.037). Variables associated with early mortality in those patients with CRCP were atherosclerotic heart disease, concurrent coronary artery bypass, aortic cross clamp time, pump time, and sepsis. The use of RCP in this retrospective analysis of a large clinical series was found to significantly and favorably influence both in-hospital mortality and the incidence of permanent stroke, although the period of HCA may be tolerable HCA alone in most patients.

Okita and associates[21] from the National Cardiovascular Center of Japan also reported similar results and concluded that prolonged HCA and RCP for longer than 60 minutes was not a risk factor for mortality or stroke in patients who underwent aortic arch surgery. However, the prevalence of transient delirium necessitates further investigation. Their logistic regression analysis demonstrated that the risk factors for mortality were ruptured aneurysm, chronic obstructive pulmonary disease, arterial cannulation in the ascending aorta, and stroke.

We have also reported on a retrospective review of 249 patients who underwent aortic arch surgery at three Japanese cardiovascular centers where HCA with RCP was a routine adjunct.[22] The subjects came from three Japanese hospitals: Tenri Hospital; National Cardiovascular Center; Tokyo Women's Medical College between January 1994 and December 1996. The pathology of the aortic arch was atherosclerotic aneurysm in 133 patients and dissection in 116. Seventy patients had surgery on an emergency basis. The hospital mortality was 25/249 (10%). Stroke developed in 11 patients (4%). The median duration of RCP was 46 minutes (range, 5 to 95 minutes). Multivariate logistic analysis revealed that pump time (p=0.0001), age (p=0.0001), and RCP time (p=0.052) are the most significant risk factors. The risk factors for mortality and neurological morbidity are pump time (p=0.0001), age (P=0.0002), urgency of surgery (p=0.07), and RCP time (p=0.15).

Our current results of aortic arch surgery using CRCP and HCA were generally satisfactory in patients who underwent elective surgery. However, the long-term results of total arch replacement for patients older than 70 years in particular emergent TAA surgery, and patients suffering from postoperative CNS injury were poor. Although prolonged duration of HCA may contribute to these poor results, other factors such as emergency surgery, late death due to aging, and systemic atherosclerosis with severe aortic atheroma are considered to be major risk factors. Since 1999, to improve the surgical results in high risk patients, we have introduced the "Arch first technique" during a short period of HCA and RCP following antegrade cerebral perfusion. HCA time was shortened to within 30 minutes. The results of surgery in 15 consecutive patients using the "Arch first technique" were better. Svensson and colleagues[25] also described a combination of retrograde and antegrade cerebral perfusion on a selective basis in patients with severe atheroma or at high risk for embolic stroke. Nevertheless, RCP may potentially reduce the risk of stroke related to embolic material. The technical simplicity of CRCP togethet with a highly favorable impact upon stroke rates and survival after aortic arch surgery justifies continued clinical use of CRCP in patients requiring HCA.

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