Repair of ascending and transverse aortic arch

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Objectives: This is a report to update our experience with repairs of the ascending and transverse arch, with an emphasis on the protective measures, including retrograde cerebral perfusion and blood flow and neurologic monitoring.

Methods: Retrospective data were collected from January 1991 to February 2010, and analysis was conducted on 1193 patients who had aneurysms involving the ascending aorta and arch.

Results: The 30-day mortality rate was 9.3%, but with a normal glomerular filtration rate, the mortality rate was 3%. In univariate analysis of the risk factors for death, the factors were advancing age of greater than 72 years (mortality, 14.8%; $P = .002$), the presence of coronary artery disease (mortality, 13.5%; $P = .02$), aortic pathology of acute dissection (mortality, 13.9%; $P = .004$), the emergency nature of the operation (mortality, 16.1%; $P = .0001$), and renal function in the lowest 3 quartiles of glomerular filtration rate (mortality, 6.9%, 10%, and 18.3%; $P = .03$, .0005, and .0001, respectively, with decreasing glomerular filtration rate). The highest quartile for pump time (>179 minutes) had a mortality rate of 18.1% ($P = .0001$). The overall stroke rate was 3%. In univariate analysis of risk factors for stroke, the stroke rate was 2.8% with and 4.2% without retrograde cerebral perfusion ($P = .30$), but when circulatory arrest time exceeded 40 minutes, the stroke rate was 1.7% with and 30% without retrograde cerebral perfusion ($P = .002$). Risk factors included age greater than 62 years (stroke rate, 4%; $P = .04$), hypertension (stroke rate, 3.7%; $P = .03$), emergency operations (stroke rate, 4.9%; $P = .04$), and glomerular filtration rate of less than 56 (stroke rate, 4.3%; $P = .05$). In multiple logistic regression for risk factors for stroke, age was associated with an odds ratio of 1.04 ($P = .008$), and emergency conditions had an odds ratio of 2.17 ($P = .03$).

Conclusions: Retrograde cerebral perfusion was associated with a trend toward a reduced incidence of hospital mortality and, in patients receiving prolonged hypothermic circulatory arrest, a reduced incidence of stroke. (J Thorac Cardiovasc Surg 2011;142:630-3)

The optimal strategy for cerebral protection during ascending and transverse aortic arch repair remains undetermined. Since the study by Griepp and colleagues[1] reporting the initial use of profound hypothermic circulatory arrest for transverse arch repairs, 2 cerebral protective approaches have emerged: retrograde cerebral perfusion (RCP) and antegrade cerebral perfusion (ACP). Ueda and associates[2] first reported RCP used in conjunction with profound hypothermic circulatory arrest during ascending and transverse arch repairs. Reported advantages of RCP were flushing out of atheromatous debris, uniform cerebral cooling, ease of use, and potential nutritive support.[2-4] ACP, which is used by the majority of groups, claimed improved neurologic outcomes during arch repair.[5] It was suggested that providing ACP would allow for a longer duration of cerebral protection because of the improved ability to provide direct nutritive flow and oxygen to cerebral tissues.[6-12] The difficulty in assessing the efficacy of these approaches, however, has been related to the varying cannulation strategies, differing monitoring approaches, and use of combinations of techniques.

We adopted the use of RCP as the main method of cerebral protection in 1993 following animal and clinical results.[13,14] Since that time, we have reported good results regarding neurologic outcome during ascending and arch repairs.[3] This report updates our experience with RCP with repairs of the ascending and transverse arch aorta.

MATERIALS AND METHODS

Patients

Based on data collection between January 1991 and February 2010, our group repaired 1290 aneurysms involving the ascending aorta and arch. Complete data were available on 1193 cases, and these comprised our study sample. The median age of the patient was 65 years and ranged from ages 16 to 93 years. The cases included 754 (63%) male and 439 (37%) female subjects. The mortality rate of the study sample (112/1193 [9.3%]) was not different from that of the excluded population (15/97 [15.4%]), indicating that the sample analyzed is representative of the census ($P = .07$).

Stroke was defined as any gross focal neurologic brain injury, either temporary or permanent, as identified on neurologic examination by a neurology consultant and confirmed with computed tomographic scanning or magnetic resonance imaging. Emergency/urgent cases included rupture,

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Abbreviations and Acronyms
ACP = antegrade cerebral perfusion
GFR = glomerular filtration rate
RCP = retrograde cerebral perfusion

acute dissection, and symptomatic aneurysms related to infection or fistulas.

Technique

Our methods for repairing ascending and arch aneurysms have been described previously.[15-17] We use cardiopulmonary bypass, profound hypothermia, circulatory arrest, and RCP. We monitor cerebral function with infrared spectroscopy or power mode transcranial Doppler scanning to confirm the presence of cerebral circulation. A 10-lead electroencephalogram is used to monitor brain function. The patient is cooled until the electroencephalogram is isoelectric. This usually coincides with a nasopharyngeal temperature of between 20°C and 15°C. Once that temperature is achieved and the pupils are fixed and dilated, cardiopulmonary bypass is discontinued and circulatory arrest is established. RCP through the superior vena caval cannula is initiated. The flow rate varies based on the information obtained from the power mode transcranial Doppler ultrasound and bilateral infrared spectroscopic analysis. This is to demonstrate the adequacy of RCP, as determined by the presence of reversed flow in the middle cerebral artery. In the past, we found that the high opening pressure required to maintain the flow is usually less than 500 mL/min. We were able to maintain the pressure of the superior vena cava at less than 25 mm Hg.

The arch is generally repaired by resecting the 2 lateral walls and the lesser curvature and replacing it with a Dacron graft. If there is an aneurysm present in the descending or thoracoabdominal aneurysm, then we use the standard elephant trunk technique with a collared graft.[18] The graft is inserted into the descending thoracic aorta at about 10 to 15 cm, and the collar ring is sewn to the thoracic aorta distal to the left subclavian artery. A side hole is made in the graft for reattachment of the cerebral and subclavian vessels. Bleeding points are secured, cerebral perfusion is restarted, and systemic circulation is allowed to flow through the sidearm, which is premanufactured and attached to the graft. The patient's head is raised, and the body is rewarmed.

Then we turn our attention to the tubular portion of the ascending aorta, which we excise, and suture our graft above the supracoronary ascending aorta. In cases in which the aortic root is dilated, the root is replaced with a composite valve graft prosthesis. In the event of acute dissection, we reconstruct the aortic root and resuspend the valve and reattach the reconstructed supracoronary ascending aorta to the graft.

Once the distal anastomosis is accomplished, we rewarm the patient's heart to a myocardial septal temperature of 30°C, and then we release the ascending aortic clamp and restore the flow to the coronary circulation. Once the patient's core body temperature is 36°C and they are able to maintain good systemic blood pressure and sinus rhythm, they are weaned from cardiopulmonary bypass.

The Committee for the Protection of Human Subjects at the University of Texas Medical School at Houston approved review of the data collected for this study. Consent was waived for the retrospective analysis.

RESULTS

The 30-day mortality rate was 9.3%, or 112 of 1193, but with a normal glomerular filtration rate (GFR), the mortality rate was 3%. The hospital mortality was 9.1% (109/1193). Table 1 shows the univariate analysis of the risk factors for death, which were advancing age of greater than 72 years (mortality, 14.8%; $P = .002$), the presence of coronary artery disease (mortality, 13.5%; $P = .02$), aortic pathology of acute dissection (mortality, 13.9%; $P = .004$), the emergency nature of the operation (mortality, 16.1%; $P = .0001$), and renal function in the lowest 3 quartiles of GFR (mortality, 6.9%, 10%, and 18.3%; $P = .03$, .0005, and .0001, respectively, with decreasing GFR). The highest pump time range (>179 minutes) had a mortality rate of 18.1% ($P = .0001$). The overall stroke rate was 3%.

Table 2 shows the univariate analysis of risk factors for stroke. For all cases, the stroke rate was 2.8% with and 4.2% without RCP ($P = .30$), but for cases in which circulatory arrest time exceeded 40 minutes, the stroke rate was 1.7% with and 30% without RCP ($P = .002$). Risk factors

TABLE 1. Univariate analysis of mortality risks

Variable	Total (%)	Deaths (%)	OR	95% CI	P value
Total	1193 (100)	112 (9.3)			
Age					
≤55	298 (25.0)	20 (6.7)			
56–64	301 (25.2)	14 (4.7)	0.68	0.34–1.37	.28
65–71	277 (23.2)	31 (11.2)	1.75	0.98–2.86	.06
≥ 72	317 (26.6)	47 (14.8)	2.21	1.34–3.64	.002
Female sex	439 (36.8)	43 (9.8)	1.08	0.72–1.61	.71
Male sex	754 (63.2)	69 (9.2)	1		
HTN	872 (73.1)	77 (8.8)	0.79	0.52–1.21	.27
No HTN	321 (26.9)	35 (10.9)	1		
COPD	248 (20.8)	24 (9.7)	1.04	0.65–1.68	.87
No COPD	945 (79.2)	88 (9.3)	1		
CAD	237 (19.9)	32 (13.5)	1.71	1.01–2.65	.02
No CAD	956 (80.1)	80 (8.4)	1		
Pathology					
Acute dissection	296 (24.8)	41 (13.9)	1.75	1.19–2.56	.004
Chronic dissection	215 (18.0)	17 (7.9)	1.00	0.59–1.69	1.0
Aneurysm	682 (57.2)	54 (7.9)	1		
Emergency	285 (23.9)	46 (16.1)	2.46	1.64–3.67	.0001
Elective	908 (76.1)	66 (7.3)			
GFR					
≤56	279 (23.4)	51 (18.3)	6.09	3.06–2.14	.0001
57–78	310 (25.9)	31 (10.0)	3.33	1.62–6.88	.0005
79–106	304 (25.5)	21 (6.9)	2.30	1.07–4.95	.03
≥107	300 (25.2)	9 (3.0)	1		
Pump time (min)					
Not reported		14			
≤119	299 (25.3)	18 (6.0)	1		
120–146	293 (24.9)	16 (5.5)	0.91	0.47–1.74	.76
147–178	294 (24.9)	21 (7.1)	1.19	0.65–2.18	.58
≥179	293 (24.9)	53 (18.1)	3.01	1.81–5.00	.0001
RCP	1002 (84.0)	87 (8.6)	0.63	0.39–1.01	.055
No RCP	191 (16.0)	25 (13.1)			

OR, Odds ratio; *CI*, confidence interval; *HTN*, hypertension; *COPD*, chronic obstructive pulmonary disease; *CAD*, coronary artery disease; *GFR*, glomerular filtration rate; *RCP*, retrograde cerebral perfusion.

ACD