ACD

Total arch replacement using moderate hypothermic circulatory arrest and unilateral selective antegrade cerebral perfusion

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Objective: To examine the clinical outcomes and impact of using moderate hypothermic circulatory arrest (MHCA) and unilateral selective antegrade cerebral perfusion (uSACP) in the setting of total aortic arch replacement (TOTAL).

Methods: From 2004 to 2012, 733 patients underwent open arch reconstruction with MHCA and SACP. Of these, 145 (20%) underwent TOTAL. Measured outcomes included death, stroke, temporary neurologic dysfunction (TND), and renal failure. Mean follow-up time was 33 months and ranged from 0 to 95 months.

Results: Core temperature at the onset of MHCA was 25.8°C. Cardiopulmonary bypass and myocardial ischemic times were 236 minutes and 181 minutes, respectively. Twenty-three patients (16%) underwent emergency repair of acute type A dissection. Fifty-four cases (37%) were reoperative and 52 (34%) were stage I elephant trunk procedures. Concomitant root replacement was performed in 50 (35%) patients, including 20 David V valve-sparing procedures. Mean duration of circulatory arrest was 55 minutes. Operative mortality was 9.7%. Overall incidence of stroke and TND was 2.8% and 5.6%, respectively. Four patients (2.8%) required postoperative dialysis. Seven-year survival was significantly reduced ($P = .04$) after repair of type A dissection (83.8%) compared with elective surgery (89.5%). Higher temperature during TOTAL was not found to be a significant risk factor for adverse events.

Conclusions: TOTAL using MHCA and uSACP can be accomplished with excellent early and late results. MHCA was not associated with adverse neurologic outcomes or higher operative risk, despite prolonged periods of circulatory arrest. (J Thorac Cardiovasc Surg 2014;147:1488-92)

Griepp and colleagues'[1] original series of successful total arch replacements used deep hypothermic circulatory arrest (DHCA) alone for cerebral protection. Since that landmark publication, advances in surgical technique and methods of cerebral protection have improved outcomes after surgical therapy for diseases of the aortic arch. Contemporary methods of cerebral protection during aortic arch surgery include moderate (core temperature >22°C) rather than profound hypothermia and the addition of continuous cerebral perfusion (antegrade or retrograde) during the period of circulatory arrest.[2-6] The debate regarding the optimal method of cerebral protection for aortic arch surgery remains unsettled. However, there seems to be a current consensus that for the prolonged periods of circulatory arrest required for total arch replacement, antegrade cerebral perfusion is warranted.[7,8]

In 2004, a protocol of moderate hypothermic circulatory arrest (MHCA) with unilateral selective antegrade cerebral perfusion (uSACP) via right axillary artery cannulation was instituted at Emory for all cases involving arch replacement. This technique has produced acceptable outcomes with low rates of adverse neurologic events in both elective and emergency cases.[2,9] Our previous publications have focused primarily on the safety of the technique with hemiarch reconstruction alone. Total arch replacement with individual reimplantation of the great vessels (TOTAL) is a more complex and challenging procedure, which requires a prolonged period of circulatory arrest. This report examines the safety of MHCA/uSACP in both elective and emergency TOTAL.

METHODS

This study was conducted with the approval of the Institutional Review Board at Emory University in compliance with Health Insurance Portability and Accountability Act regulations and the Declaration of Helsinki. The Institutional Review Board waived the need for individual patient consent. A review of the Emory Aortic Surgery Database from 2004 to 2012 identified 733 patients who underwent open arch reconstruction with MHCA and uSACP via right axillary artery cannulation; 145 (20%) of these patients underwent TOTAL and are the subject of this report. Twenty-three TOTAL patients (16%) underwent complete arch replacement during emergency repair of an acute type A aortic dissection. The remaining 122 patients underwent elective TOTAL.

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Abbreviations and Acronyms

CABG = coronary artery bypass grafting
CI = confidence intervals
DHCA = deep hypothermic circulatory arrest
MHCA = moderate hypothermic circulatory arrest
PND = permanent neurologic dysfunction
TND = temporary neurologic dysfunction
uSACP = unilateral selective antegrade cerebral perfusion
TOTAL = total aortic arch replacement

Surgical Technique

The technical details of our operative technique have been published previously.[2] Core body temperature was measured via a temperature probe connected to a Foley catheter. Transcutaneous bilateral cerebral oximetry (INVOS 3100-SD, Troy, Mich) and continuous electroencephalogram monitoring were routinely performed. Intraoperative transesophageal echocardiography was used in all patients.

All procedures began with an 8-mm Gelweave (Vascutek Terumo, Inchinnan, United Kingdom) graft sewn end to side to the right axillary artery. After median sternotomy, the right atrium was cannulated and the patient was placed on cardiopulmonary bypass. Systemic cooling was initiated and a left ventricular vent was placed via the right superior pulmonary vein. The goal core body temperature at the initiation of circulatory arrest was determined by multiple factors including age, renal function, and complexity of the planned total arch reconstruction. Once the goal temperature was reached, the innominate artery was occluded at the initiation of the lower body circulatory arrest period. Unilateral selective antegrade cerebral perfusion was initiated at 16°C-18°C at 10 mL/kg/min. Flow was adjusted to maintain a cerebral perfusion pressure of 60-70 mm Hg, which was measured off a side port from the axillary cannula.

After initiation of the circulatory arrest period, resection of all aortic arch pathology was performed. Indications for TOTAL in the emergency setting were complete destruction of the arch tissue from the dissection process or aneurysmal arch disease more than 5.0 cm. The innominate, left carotid, and left subclavian arteries were all clamped and then separated off the arch as individual vessels. Total arch replacement was defined as separate reimplantation of all supraaortic vessels and was performed using a 4-branch modified arch Gelweave graft. Once the distal aortic and left subclavian anastomoses were complete, a perfusion limb of the graft was cannulated with a separate 22-Fr elongated arterial cannula (Medtronic, Inc, Minneapolis, Minn) to restore full cardiopulmonary bypass and end the circulatory arrest period to the lower body. On completion of the circulatory arrest period, vigorous deairing maneuvers were performed before reinstitution of full flow cardiopulmonary bypass and rewarming was initiated. The left common carotid branch anastomosis was performed next, followed by all proximal aortic procedures (root, valve, coronary, and so forth). Once the neo-sinotubular junction anastomosis was complete, the crossclamp was removed. The innominate artery anastomosis was performed after the crossclamp was removed during the period of cardiac reperfusion.

Statistical Analysis

All patients undergoing total arch reconstruction were subdivided into 2 groups by their elective or emergency status. Variable distributions were compared across groups using 2-sample *t* tests for numerical variables and χ^2 tests for categorical variables. Kaplan-Meier product-limit estimation, in conjunction with Social Security Death Index dates, was used to calculate long-term survival in these patients. Kaplan-Meier curves were generated to compare the survival of elective versus emergency patients. Survival was compared using log-rank tests.

Multivariable logistic regression analysis was used to estimate the effect of temperature and circulatory arrest time of clinical end points: death, permanent neurologic dysfunction (PND), temporary neurologic dysfunction (TND), new renal failure, and prolonged mechanical ventilation (>48 hours). Adjustments were made for several preoperative variables: age, renal failure, redo surgery, diabetes, and chronic lung disease. Adjusted odds ratios and 95% confidence intervals (CI) were estimated. All analyses were performed using SAS version 9.3 (SAS Institute, Inc, Cary, NC). All tests were evaluated at the 0.05 alpha level.

RESULTS

Preoperative demographics for elective and emergency TOTAL patients are listed in Table 1. The mean age of all patients was 59 ± 14 years. The 2 groups were equivalent with regard to gender, stroke, diabetes, hypertension, chronic obstructive pulmonary disease, and renal failure. Elective patients had a significantly higher incidence of previous myocardial infarction ($P < .05$). Both groups had normal ventricular function (ejection fraction >55%). A higher percentage of elective patients underwent TOTAL in the setting of reoperative cardioaortic surgery (elective 43% vs emergency 4.4%, $P < .01$).

The temperature at the initiation of MHCA for the entire cohort was 25.8°C ± 2.7°C, and was slightly warmer in the emergency group (elective 25.6°C ± 2.7°C vs emergency 27.2°C ± 2.4°C; $P < .01$). Cardiopulmonary bypass and crossclamp times were 237 ± 71 minutes and 182 ± 63 minutes, respectively, and did not differ between elective and emergency cases. The mean duration of circulatory arrest was longer in the emergency group (elective 53 ± 16 minutes vs emergency 61 ± 19 minutes; $P = .06$). There was no difference in the incidence of concomitant root replacement or coronary artery bypass procedures between the groups (Table 2). Bilateral cerebral oximetry data were available for analysis for 101 (70%) patients. After 5 minutes of circulatory arrest, the right and left cerebral oximetry had changed by +1.7% and −5.9% from baseline, respectively. After 15 minutes of circulatory arrest, the right and left cerebral oximetry had changed by +6.1% and −1.2% from baseline, respectively.

Operative mortality for the entire series was 9.7% (elective 10.7% vs emergency 4.3%; $P = .34$). The causes of death included multisystem organ failure (n = 6), right ventricular failure (n = 3), intractable hemorrhage (n = 2), ruptured abdominal aortic aneurysm (n = 1), hypoxic brain injury (n = 1), and colonic perforation (n = 1). The overall incidence of PND and TND was 2.8% and 5.6%. PND occurred more commonly in emergency patients and TND was more frequent in elective patients. The overall incidence of dialysis-dependent renal failure was 2.8% and there was no difference between