Open Surgical Repair Remains the Gold Standard for Treating Aortic Arch Pathology

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Background. **Endovascular arch repair technology is driven in large part by the assumption that open arch operations are high-risk. We wanted to evaluate the clinical results of open arch reconstruction in the modern era in a large group practice.**

Methods. **From October 2003 to June 2014, 567 patients underwent aortic arch operations: hemiarch repair was performed in 429 patients (75.7%; group A), total arch repair in 129 (22.7%; group B), and patch repair in the remaining 9 (1.6%). The procedure was an emergency in 88 patients (20.5%) in group A and in 41 patients (31%) in group B. Redo sternotomy after a previous aortic operation was performed in 35 patients (8.2%) in group A and in 28 patients (22%) in group B.**

Results. **Permanent neurologic deficits were diagnosed in 12 patients (2.8%) in group A and in 3 patients (2.4%) in group B. No spinal cord injuries occurred. Mortality at 30 days was 4% (17 patients) in group A and 5.4% (7 patients) in group B. Patients in group A were younger than in group B (mean age, 61.3 vs 63.6 years; $p = 0.06$). Older age (odds ratio, 1.05; 95% confidence interval, 1.01 to 1.09; $p = 0.0087$) and extracorporeal circulation time (odds ratio, 1.01; 95% confidence interval, 1 to 1.01; $p < 0.001$) were predictors of perioperative 30-day mortality. Age (odds ratio, 1.05; 95% confidence interval, 1.01 to 1.08; $p = 0.006$) was the only predictor for neurologic dysfunction. Survival at 2, 6, and 8 years was 90%, 80%, and 69%, respectively, for group A, and 85%, 70% and 62%, respectively, for group B.**

Conclusions. **These results set a standard against which endovascular technology needs to be compared.**

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Open repair for aortic arch aneurysm is considered particularly complex and challenging because of the potential for neurologic injury. Cooley and colleagues [1] in 1955 reported the use of hypothermia to protect the brain during aortic arch reconstruction. In 1975, Griepp and colleagues [2] published a series of 4 patients undergoing resection of aortic arch aneurysms with hypothermia achieved by a combination of surface cooling and cardiopulmonary bypass (CPB).

As complexity of arch reconstructions increased, cardiac surgeons introduced antegrade (ACP) and retrograde cerebral perfusion (RCP) to achieve more reliable neurologic protection [3, 4]. Although the analogy of brain protection to cardioplegia has its limitations, the practice and science of selective cerebral perfusion has allowed safer complex arch repairs and less reliance on hypothermia alone.

Concomitant with achievement of safer open aortic arch repairs, endovascular repairs have found an increasing role in the treatment of abdominal, thoracic, and more recently, thoracoabdominal aortic aneurysms. The aortic arch represents the next frontier for endovascular repairs. The assumption that open aortic arch operations carry a high risk of death and neurologic injury has pushed many cardiovascular circles toward the adoption of endovascular repairs as hybrids or as closed chest approaches.

We report our recent state of the art of aortic arch operations as practiced in a large volume institution.

Patients and Methods

The Mayo Clinic College of Medicine Institutional Review Board approved this study. All patients reviewed provided informed consent. Between October 2003 and June 2014, 567 patients underwent aortic arch reconstruction through a median sternotomy using hypothermic circulatory arrest (HCA) at Mayo Clinic, Rochester, MN. The study excluded 9 patients (1.6%) who underwent limited patch repair. Hemiarch repair was performed in 429 patients (75.7%; group A) and total arch repair was performed in 129 patients (22.7%; group B). The mean age

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Abbreviations and Acronyms

ACP = antegrade cerebral perfusion
AV = aortic valve
CABG = coronary artery bypass grafting
CI = confidence interval
CPB = cardiopulmonary bypass
ECMO = extracorporeal membrane oxygenator
EEG = electroencephalography
HCA = hypothermic circulatory arrest
MV = mitral valve
NYHA = New York Heart Association
OR = odds ratio
PND = permanent neurological deficit
RCP = retrograde cerebral perfusion
SACP = selective antegrade cerebral perfusion
ST = sinotubular
TND = temporary neurological deficit

at the time of the operation was 61 ± 14 years (range, 18 to 91 years) for hemiarch patients (68% male) and 64 ± 14 years (range, 26 to 86 years) for total arch patients (65% male). The clinical characteristics of these 558 patients are reported in Table 1.

Study Design, Definitions, and Variables

The electronic medical records were retrospectively reviewed and analyzed. Operative mortality was defined as all-cause mortality within 30 days of the operation. Permanent neurologic deficit (PND) was defined as new focal deficit that persisted more than 72 hours. Radiologic confirmation was obtained in all of these patients. Temporary neurologic deficit (TND) was defined as new onset of cerebral injury documented as confusion, seizure, or encephalopathy, or a new focal deficit lasting less than 72 hours without any new structural abnormality observed on imaging.

The operation was defined as an emergency when the patient was taken to the operating room once the diagnosis was established and as urgent when performed within 24 hours of the diagnosis. CPB was defined as the period the patient was on CPB, including the circulatory arrest time. Circulatory arrest time was the period when part or all of the body received no circulatory support and for the brain was defined as the period when the brain did not receive perfusion of any kind.

Intraoperative Management

Eight surgeons performed the aortic arch repairs during a period of 10 years. There was no standardized surgical technique. The choice of cerebral protection and the cannulation strategy was left to the surgeon's discretion. Operative details, including concomitant procedures, and intraoperative perfusion data are reported in Tables 2 and 3.

Bladder and nasopharyngeal temperatures were monitored in all patients. The most common arterial cannulation site was the distal ascending aorta for patients undergoing hemiarch replacements (298 [69.5%]) and the axillary artery for total arch patients (72 [55.8%]). HCA alone was used in many of the hemiarch repairs. Selective ACP (SACP) was used in most total arch repairs, with the axillary artery as the most commonly used perfusion route.

Late in the study, the distal ascending aorta was commonly cannulated over a wire using the Seldinger technique guided by transesophageal echocardiography. Neurophysiologic monitoring with intraoperative electroencephalography (EEG) was used recently in elective cases to guide core cooling to a flatline EEG. In addition to hypothermia, RCP was selectively used through a snared superior vena cava cannula at flow rates of 200 to 300 mL/min to maintain a superior vena cava pressure of 15 to 20 mm Hg. RCP was primarily used in hemiarch repairs and as a technique to remove air during total arch reconstructions. Once the arch anastomosis was completed, the arch Dacron (DuPont, Wilmington, Del) graft was directly cannulated, and antegrade CPB was resumed.

Table 1. Preoperative Characteristics

Variable[a]	Hemiarch (n = 429)	Total Arch (n = 129)	*p* Value[b]
Age, y	63 (18–91)	67 (26–86)	0.07
Male gender	290 (67.6)	84 (65.1)	0.59
COPD	364 (84.8)	95 (73.6)	0.003
Previous stroke	37 (8.6)	14 (10.9)	0.44
Redo surgery	106 (24.8)	57 (44.2)	<0.0001
Previous proximal aortic operation	35 (8.2)	28 (22)	<0.0001
Chronic renal dysfunction	43 (10)	22 (17.1)	0.03
Renal insufficiency requiring dialysis	4 (0.9)	0	0.27
Maximum aortic diameter, mm	53 (6.2–110)	55.1 (41–85)	0.004
Peripheral vascular disease	34 (7.9)	23 (17.8)	0.001
Carotid vascular disease	56 (13.1)	27 (20.9)	0.027
Preoperative ejection fraction	0.61 (0.18–0.79)	0.62 (0.29–0.76)	0.09
Connective tissue disorder			0.04
Bicuspid aortic valve	139 (75.5)	16 (48.5)	
Marfan syndrome	38 (20.7)	13 (39.4)	
Indication for operation			0.23
Aneurysm	319 (74.4)	96 (74.4)	
Acute and chronic dissection	79 (18.4)	19 (14.7)	
Rupture	16 (3.7)	10 (7.8)	
Others	15 (3.5)	4 (3.1)	
Aortic regurgitation			0.03
Moderate	84 (19.6)	18 (13.6)	
Severe	88 (20.5)	18 (13.6)	

[a] Data are presented as medians and interquartile ranges for continuous variables and as number (%) for categoric variables. [b] Values of $p < 0.05$ are statistically significant.

COPD = chronic obstructive pulmonary disease.