Elective Aortic Arch Repair: Factors Influencing Neurologic Outcome in 791 Patients

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Background. **The aim of this study was to determine perioperative factors influencing neurologic outcome in a single-center cohort of patients undergoing elective aortic arch operations.**

Methods. **From January 2005 to June 2015, 791 consecutive patients received open aortic arch operations with either antegrade selective cerebral perfusion (ASCP) (636 patients [80.4%]) or deep hypothermic circulatory arrest (DHCA) (155 patients [19.6%]). Main indications were degenerative aneurysm (85%) and chronic postdissection aneurysm (9.1%).**

Results. **Hospital mortality (30 days) was 5.3%. Permanent neurologic dysfunction (PND) was observed in 42 patients (5.3%). Significant risk factors for PND appeared to be femoral artery cannulation ($p = 0.003$), progressive cardiopulmonary bypass ($p = 0.001$), circulatory arrest ($p = 0.001$), and ASCP time ($p = 0.011$). ASCP, in contrast to DHCA, was protective against PND (odds ratio [OR], 0.37; $p = 0.003$). Temporary neurologic dysfunction (TND) was observed in 49 patients (6.2%). Preoperative transient ischemic attack (TIA) ($p = 0.001$), progressive EuroSCORE ($p = 0.001$), left ventricular ejection fraction (LVEF) less than 50% ($p = 0.003$), and the use of femoral artery cannulation ($p = 0.049$) showed correlation in the univariate analysis. Stepwise logistic regression indicated TIA ($p = 0.002$; OR, 3.24) and the EuroSCORE ($p = 0.003$; OR, 1.23) as independent predictors of TND.**

Conclusions. **Contemporary elective aortic arch repair can be achieved with low mortality and a low incidence of neurologic dysfunction. ASCP was confirmed to be the safest method of cerebral protection. The extent of aortic arch replacement (apart from the frozen elephant trunk [FET] procedure) was not related to increased rates of TND or PND.**

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Open operations for pathologic aortic arch conditions have advanced greatly since the introduction of deep hypothermic circulatory arrest (DHCA) in the 1970s and selective cerebral perfusion (ASCP) in the 1990s [1, 2]. Despite many refinements in surgical techniques and cerebral monitoring, aortic arch repair remains challenging, with considerable perioperative risk, including neurologic deficits. In the current endovascular era, there is increasing interest in hybrid or even complete endovascular aortic arch repair. Although less invasive, the risk of stroke is still present, as is the potentially reduced durability of this type of repair [2]. In open operations, there is large heterogeneity in the type of cerebral protection and perfusion technique used as well as in the extent of cerebral monitoring perioperatively [3]. Reported stroke rates vary greatly using DHCA alone, unilateral or bilateral ASCP, or a central or peripheral arterial cannulation site [4, 5]. For instance, in Europe among 450 cardiac surgical centers, ASCP was used as the main cerebral perfusion strategy in the acute and chronic setting in 53% and 65% of cases, respectively [6]. Because the number of centers performing open, hybrid, or total endovascular aortic arch repair continues to grow, it may become important to aim now for a standardized optimal strategy of cerebral protection intraoperatively in an attempt to further reduce the stroke rate. Our study aimed to investigate the rate of neurologic dysfunction (temporary and permanent) and the potential risk factors

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Abbreviations and Acronyms

ASCP	=	antegrade selective cerebral perfusion
AUROC	=	area under the receiver operating characteristic
CPB	=	cardiopulmonary bypass
CTA	=	computed tomographic angiography
DHCA	=	deep hypothermic circulatory arrest
EEG	=	electroencephalography
ET	=	elephant trunk
FET	=	frozen elephant trunk
LVEF	=	left ventricular ejection fraction
NIRS	=	near-infrared spectroscopy
PND	=	permanent neurologic dysfunction
TCCD	=	transcranial color-coded Doppler
TIA	=	transient ischemic attack
TND	=	temporary neurologic dysfunction

in a large single-center experience using contemporary cerebral protection and perfusion strategies. To minimize potential bias, only patients undergoing elective procedures were included in the analysis.

Patients and Methods

Patient Profile

Between January 2005 and June 2015, 791 consecutive patients underwent elective aortic arch operations using either ASCP or DHCA at the St. Antonius Hospital in Nieuwegein, the Netherlands. Medical records were reviewed for relevant perioperative data. Because of its retrospective nature, the ethical committee waived the need for informed consent. There were 456 male patients (57.6%) and 335 female patients (42.4%), with a mean age of 63 ± 11.8 years; in particular, 116 (14.7%) were older then 75 years. Seventy-eight patients (9.9%) had preexisting neurologic injury, and 140 (17.7%) patients required repeated sternotomy because of a previous cardiac or aorta-related surgical procedure. The main indications for aortic arch operations was degenerative aneurysm in 672 patients (85%) and chronic postdissection aneurysm in 72 (9.1%) patients. All preoperative data are depicted in Table 1.

Cerebral Monitoring

As part of the preoperative workup, all patients were studied extensively for existing pathologic features in cerebropetal vessels using duplex scanning and for variations in the circle of Willis using transcranial color-coded Doppler (TCCD). In the great majority of patients (~99%), brain perfusion was considered adequate by using bilateral ASCP. In only a few cases, selective perfusion of the left subclavian artery was added. Unilateral right-sided ASCP was used only intermittently (when considered safe based on preoperative TCCD results) during the anastomosis to the left common carotid artery during a separate grafting technique. Intraoperative cerebral monitoring was achieved by a multimodal approach, including electroencephalography (EEG), regional oxygen saturation in the bilateral frontal lobes with near-infrared spectroscopy (NIRS), bilateral TCCD, and bilateral radial artery pressure lines. The TCCD provided immediate feedback on the functioning of the antegrade perfusion cannulas, as well as the occurrence of emboli to optimize our air removal strategy. The electroencephalogram informed us about complete electrocerebral silence as a sign of a uniform cerebral protection using DHCA, independent of the actual nasopharyngeal temperature. In case of ASCP, EEG and NIRS were considered additional measures to evaluate adequate brain protection.

Operative Technique

All patients were operated on using a midsternal approach. After systemic heparinization, cardiopulmonary bypass (CPB) was instituted with a cannula for arterial return to either the ascending aorta or the common femoral artery, and a venous single 2-stage cannula in the right atrium in the vast majority of patients (in anticipated hostile reentry, femoral venous cannulation was used as an alternative). In this series of elective aortic arch operations, it was possible to cannulate the ascending aorta directly most of the time; when not considered safely possible, as in the case of hostile reentry, chronic aortic dissection, or severe calcification of

Table 1. Patient Demographics (N = 791)

Variable	Frequency	%
Male sex	456	57.6
Age (y, mean ± SD)	63 ± 11.8	
Age ≥ 75 y	116	14.7
Hypertension	362	45.8
Diabetes	72	9.1
Obesity (BMI ≥30)	142	18
COPD	95	12
Left ventricular ejection fraction (≤30)	4	0.5
Cerebrovascular disease	78	9.9
Marfan syndrome	23	2.9
Bicuspid aortic valve	128	16.2
Cause		
Degenerative aneurysm	672	85
Chronic postdissection aneurysm	72	9.1
Infection	9	1.1
Pseudoaneurysm	15	1.9
Connective tissue disorder	20	2.5
Other	3	0.4
Cardiac reoperation	140	17.7
CABG	11	1.4
AVR	39	4.9
Aortic root	39	4.9
Ascending aorta	68	8.6
Arch	15	1.9

AVR = aortic valve replacement; BMI = body mass index; CABG = coronary artery bypass grafting; COPD = chronic obstructive pulmonary disease.