What Is the Best Strategy for Brain Protection in Patients Undergoing Aortic Arch Surgery? A Single Center Experience of 636 Patients

Martin Misfeld, MD, PhD,* Sergey Leontyev, MD,* Michael A. Borger, MD, PhD, Olivier Gindensperger, Sven Lehmann, MD, Jean-Francois Legare, MD, and Friedrich W. Mohr, MD, PhD

Department of Cardiac Surgery, Heart Center, University of Leipzig, Leipzig, Germany

Background. Cerebral protection during aortic arch surgery can be performed using various surgical strategies. We retrospectively analyzed our results of different brain protection modalities during aortic arch surgery.

Methods. Between January 2003 and November 2009, 636 consecutive patients underwent aortic arch replacement surgery using unilateral antegrade cerebral perfusion (UACP [n = 123]), bilateral antegrade cerebral perfusion (BACP [n = 242]), retrograde cerebral perfusion (RCP [n = 51]), or deep hypothermia and circulatory arrest (DHCA [n = 220]). Mean age of patients was 62 ± 14 years, 64% were male, 15% were reoperations, and 37% were performed for acute type A dissections. Mean follow-up was 4.9 ± 0.1 years and was 97% complete.

Results. Circulatory arrest time was 22 ± 17 minutes UACP, 23 ± 21 minutes BACP, 18 ± 12 minutes RCP, and 15 ± 13 minutes DHCA; $p < 0.001$). Early mortality was 11% (n = 72) and was not different between the surgical groups. Stroke rate was 9% for ACP patients (n = 33) versus 15% (n = 39) for patients who did not receive ACP ($p = 0.035$). Independent predictors of stroke were type A aortic dissection (odds ratio [OR], 1.9; 95% confidence interval [CI], 1.3 to 3.2; $p < 0.001$), age (OR, 1.04; 95% CI, 1.01 to 1.06; $p = 0.001$), duration of circulatory arrest (OR, 1.01, 95% CI, 1.002 to 1.03; $p = 0.02$), and total aortic arch replacement (OR, 2.7; 95% CI, 1.3 to 5.7; $p = 0.005$). Five year survival was 68% ± 4% and was not significantly different between groups.

Conclusions. Antegrade cerebral perfusion is associated with significantly less neurologic complications than RCP and DHCA, despite longer circulatory arrest times. Medium-term survival is worse for patients with postoperative permanent neurologic deficit and preoperative type A aortic dissection.

(Ann Thorac Surg 2012;93:1502–9)

Aortic arch surgery with deep hypothermic circulatory arrest (DHCA) is still a surgical challenge associated with increased mortality and a significant risk of permanent neurologic injury [1–3]. Different cerebral protection strategies have been used during operative treatment of various pathologies of the aortic arch, such as atherosclerotic aneurysms or type A aortic dissection. We herein present the results of different cerebral protection options that have been employed at our institution during aortic arch surgery over a 7-year period. Our cerebral protection strategy has evolved from the use of DHCA alone, to DHCA with a short duration of retrograde cerebral perfusion (RCP), to moderate hypothermia with unilateral antegrade cerebral perfusion (UACP) or bilateral antegrade cerebral perfusion (BACP), over the study period. This evolvement in our strategy allows us to retrospectively review and assess the outcomes associated with each cerebral protection technique.

Accepted for publication Jan 31, 2012.

*Drs Martin Misfeld and Sergey Leontyev contributed equally.

Address correspondence to Dr Leontyev, Universität Leipzig, Herzzentrum, Klinik für Herzchirurgie, Strümpellstr 39, Leipzig 04289, Germany; e-mail: sergey.leontyev@med.uni-leipzig.de.

The objectives of this study were, therefore, (1) to describe the clinical characteristics of patients undergoing aortic arch surgery; (2) to compare the clinical outcome of patients with different strategies of cerebral protection; and (3) to determine predictors of mortality, neurologic complications, and midterm survival for such patients and, therefore, to determine the safest method for aortic arch surgery with regard to neurologic protection.

Patients and Methods

Between January 2003 and November 2009, 636 consecutive patients underwent partial or total aortic arch surgery at the Leipzig Heart Center. All patients were included in our analysis. Data were prospectively collected in a database for later analysis. Retrospective data analysis of our database was approved by the local Ethics Committee. An individual consent for the study was waived.

Choice of cerebral protection strategy was left to the discretion of the surgeon. As stated above, however, our preferred cerebral protection strategy slowly evolved from DHCA alone, to DHCA with a brief duration of

0003-4975/$36.00
doi:10.1016/j.athoracsur.2012.01.106

Abbreviations and Acronyms

ACP	= antegrade cerebral perfusion
BACP	= bilateral antegrade cerebral perfusion
CI	= confidence interval
CPB	= cardiopulmonary bypass
DHCA	= deep hypothermic circulatory arrest
OR	= odds ratio
PND	= permanent neurologic deficit
RCP	= retrograde cerebral perfusion
UACP	= unilateral antegrade cerebral perfusion

RCP, to moderate hypothermia with either UACP or BACP over time. Patients were followed up annually by mailed questionnaire or, when needed, by contacting the referring cardiologist or family physician. Follow-up was complete for 97% of patients.

Operative Technique

All patients were operated on through a midline sternotomy. Arterial cannulation was performed through the axillary artery (arterial cannula, 6.5 mm; Sorin Group, Milan, Italy; or Fem-Flex, 18F; Edwards Lifesciences, Irvine, CA) in 53% of patients, 67% of whom presented with an acute type A aortic dissection. The ascending aorta was directly cannulated (Fem-Flex, 18F to 22F) in 33% of patients, and the femoral artery (Fem-Flex–II, 16F to 18F) was used in 14% of patients. The right atrium was cannulated with a double-stage cannula (Thin-Flex dual-stage venous drainage cannula, 29F/37F; Edwards Lifesciences), and the left ventricle was vented through the right upper pulmonary vein. Patients were cooled, and systemic circulatory arrest was established at the temperature chosen by the operating surgeon.

At the predetermined target temperature, patients were placed in the Trendelenburg position, and the head was cooled topically. In cases of right axillary cannulation, antegrade cerebral perfusion (ACP) was initiated before circulatory arrest and opening of the aorta by clamping the brachiocephalic trunk and unilateral perfusion through the right carotid artery with a flow rate of 10 $mL \cdot kg^{-1} \cdot min^{-1}$ with oxygenated cold blood at a temperature of 24°C. After partial or total arch resection, the left carotid artery was checked for sufficient back flow and, if present, clamped to prevent steal phenomenon. In complex cases, additional ACP was administered through the left carotid artery (True Flow RDB cannula, 14F to 17F; Conecto Medical, Bologna, Italy) initiated with an additional flow rate of 5 $mL \cdot kg^{-1} \cdot min^{-1}$. In cases where cannulation of the ascending aorta was performed, BACP was initiated through direct cannulation of the brachiocephalic trunk and the left common carotid artery (with True Flow RDB cannulas) after Trendelenburg positioning and circulatory arrest. The left subclavian artery was occluded with an 8/14F Fogarty occlusion catheter (Edwards Lifesciences) or with a tourniquet to prevent steal phenomenon.

The RCP was initiated through the superior vena cava before circulatory arrest was initiated with flow rate of 100 to 300 mL/min using a 24F venous cannula (Terumo, Ann Arbor, MI) and clamping of the superior vena cava above the right atrium. In the majority of such cases, however, RCP was used mainly as a method of cerebral deairing after circulatory arrest. Aortic arch surgery in patients without any form of cerebral perfusion was performed under DHCA (22°C ± 2°C). For the last 5 years, this technique has been completely replaced by UACP or BACP with moderate hypothermia.

Surgical procedures performed consisted of partial arch replacement with replacement of the ascending aorta with or without aortic root surgery (Bentall operation, valve-sparing procedure, or isolated aortic valve reconstruction or replacement). Total aortic arch replacement was reserved for patients who had extensive aneurysmal involvement of the arch or proximal descending aorta, as well as in type A aortic dissection patients with an entry site or reentry tear in the aortic arch. Such operations were performed with or without an elephant trunk procedure. The brachiocephalic vessels were reimplanted either as a complete island or separately through side arms of a multibranched graft, developed by Spielvogel and associates [4].

Definitions

In accordance with The Society of Thoracic Surgeons guidelines, early mortality was defined as all-cause mortality at 30 days [5]. Operations were considered emergent if performed within 24 hours of hospital admission for cardiovascular instability, and as urgent if performed during the same hospital admission.

All patients with suspected neurologic complications on physical examination underwent computed tomography or magnetic resonance imaging. Neurologic complications were defined as permanent neurologic deficit (PND) for patients with stroke, and temporary neurologic deficit for patients with reversible deficits. Stroke was defined as a new postoperative focal neurologic deficit that persisted more than 72 hours, or a new focal lesion of the brain detected by computer tomographic scanning. Temporary neurologic deficit was defined as a focal neurologic deficit lasting less than 72 hours, or postoperative delirium, agitation, confusion, or decreased level of consciousness without any new structural abnormality observed on imaging [6, 7].

Statistical Analysis

Continuous variables are expressed as mean ± SD and categorical data as proportions. Categorical variables were compared using the χ^2 test or Fisher's exact test. Independent continuous variables were compared by unpaired Student's *t* test for comparison of normally distributed data between two groups or Kruskal-Wallis for the comparison of more than two groups, as appropriate.

We examined 34 potential preoperative risk factors for early and late mortality by univariate and multivariate testing (Table 1). Dichotomous adverse perioperative or postoperative outcome events were analyzed using a univariate and multivariate logistic regression model