Favorable late survival after aortic surgery under straight deep hypothermic circulatory arrest

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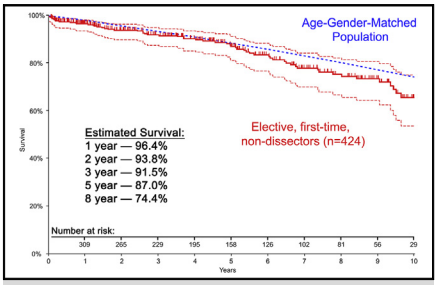
ABSTRACT

Background: Surgical and cerebral protection strategies in aortic arch surgery remain under debate. Perioperative results using deep hypothermic circulatory arrest (DHCA) have been associated with favorable short-term mortality and stroke rates. The present study focuses on late survival in patients undergoing aortic surgery using DHCA.

Methods: A total of 613 patients (mean age, 63.7 years) underwent aortic surgery between January 2003 and December 2015 using DHCA, with 77.3% undergoing hemiarch replacement and 20.4% undergoing arch replacement, with a mean DHCA duration of 29.7 ± 8.5 minutes (range, 10-62 minutes). We examined follow-up extending up to a mean of 3.8 ± 3.4 years (range, 0-14.1 years).

Results: Operative mortality was 2.9%, and the stroke rate was 2%. Survival was 92.2% at 1 year and 81.5% at 5 years, significantly lower than the values in an age- and sex-matched reference population. In elective, nondissection first-time surgeries (n = 424), survival was similar to that of the reference group. Acute type A aortic dissection (hazard ratio [HR], 4.84; $P = .000$), redo (HR, 4.12; $P = .000$), and descending aortic pathology (HR, 5.54: $P = .000$) were independently associated with reduced 1-year survival. Beyond 1 year, age (HR, 1.07; $P = .000$), major complications (HR, 3.11; $P = .000$), and atrial fibrillation (HR, 2.47; $P = .006$) were independently associated with poor survival. DHCA time was not significantly associated with survival in multivariable analysis.

Conclusions: Aortic surgery with DHCA can be performed with favorable late survival, with the duration of DHCA period having only a limited impact. However, these results cannot be generalized for very long durations of DHCA (>50 minutes), when perfusion methods may be preferable. In elective, nondissection first-time surgeries, a late survival comparable to that in a reference population can be achieved. Early survival is adversely affected by aortic dissection, redo status, and disease extent. (J Thorac Cardiovasc Surg 2017;154:1831-9)



Survival of elective, first-time nondissection cases compared with the reference population (n = 424).

Central Message

Aortic arch surgery with deep hypothermic circulatory arrest can be performed with favorable late survival.

Perspective

Deep hypothermic circulatory arrest is a safe technique for cerebral protection in aortic arch surgery. We show that late survival is also favorable, especially in patients undergoing the procedure electively.

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Within the past 60 years, thoracic aortic surgery has seen a spectacular evolution. Nevertheless, uncertainties persist, mainly regarding surgical strategy, cerebral protection, and appropriate extent of aortic replacement. Recent studies have tended to recommend more extensive repairs and the use of moderate hypothermia with antegrade cerebral perfusion.[1,2] Main concerns regarding the use of straight deep hypothermic arrest (DHCA) center around a potentially increased risk of stroke, as well as of possible subtle neurologic damage that might impair outcomes.[1,3,4] Other groups, including our own, were able

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Abbreviations and Acronyms

ASI = aortic size index
ATAAD = acute type A aortic dissection
CI = confidence interval
DHCA = deep hypothermic circulatory arrest
HR = hazard ratio

to demonstrate favorable early outcomes with a duration of DHCA of up to 50 minutes.[5]

Expanding on our previously published positive short-term results,[5] in the present study we investigated late outcomes of DHCA for aortic arch disease and identified variables associated with late survival. We aimed to determine whether DHCA itself or increased DHCA duration negatively impacts late survival.

METHODS

Study Design

We performed a retrospective cohort study including 613 consecutive patients undergoing aortic arch surgery using straight DHCA between January 2003 and December 2015 at the Aortic Institute at Yale-New Haven. The study was approved by the Human Investigation Committee.

Patient Characteristics

The mean age of the study group was 63.7 ± 13.2 years (range, 14.0-88.0 years), and 61.2% (n = 375) of the patients were male. The indication for surgery was aortic aneurysm in most patients (n = 520; 84.8%), but 13.1% (n = 80) had aortic dissection, which was acute in 36 (5.9%). The remainder had various pathologies, including penetrating aortic ulcer, intramural hematoma, or free-floating atheroma. Eighty-four patients (13.7%) underwent urgent or emergent surgery. Aortic pathology extended into the descending aorta at initial surgery in 144 patients (23.5%).

Data on preoperative ascending aortic size was available in 473 of 478 patients undergoing elective interventions. The mean preoperative aortic size was 5.2 ± 0.6 cm (range, 3.0-8.0 cm). The mean aortic size index (ASI) (available in 422 patients) was 2.69 ± 0.45 cm/m^2 (range, 1.58-5.02 cm/m^2). In terms of ASI risk category, 261 patients were low risk (ASI <2.75 cm/m^2), 156 were intermediate risk, and 5 were high risk (ASI >4.25 cm/m^2).[6] Patient characteristics are summarized in Table 1.

Surgical and Cerebral Protection Technique

Our surgical strategy and cerebral protection technique have been described in detail previously.[5] All procedures are performed through a median sternotomy approach. Cardiopulmonary bypass is instituted, preferably via femoral artery cannulation (76.7%). Axillary (14.8%), innominate artery, or direct aortic cannulation (7.8%) is performed if the femoral artery is not safely accessible or preoperative test results suggest severe arteriosclerosis of the descending aorta, which might make retrograde perfusion unsafe. On bypass, the patient is cooled to a bladder temperature of 20°C (for hemiarch replacement) or 18°C (for arch replacement). Cooling is done gradually over at least 30 to 35 minutes, but cooling time varies widely, because cooling is usually performed during proximal reconstruction. Before and during DHCA, the patient's head is topically cooled with ice. Acid-base balance is managed using the alpha-stat method. To reduce DHCA time, the distal arch anastomosis is preferably performed proximal to the left subclavian artery, with a 2- or 3-vessel patch reimplantation of the head vessels. After DHCA, we prefer slow rewarming with a temperature gradient <10°C up to 34°C before the patient is separated from cardiopulmonary bypass. This is warm enough to protect against arrhythmias but cool enough to provide some additional neural protection. No neuromonitoring is used.

Procedural Data

The majority of patients in the present cohort underwent hemiarch replacement (n = 474; 77.3%). One hundred twenty-five patients (20.4%) underwent total arch replacement, with a conventional elephant trunk used in 85 of these patients (68.0%). In patients in whom a prompt need for descending aortic replacement is anticipated, a full elephant trunk is used, long enough to be easily accessible beyond the aortic arch during a subsequent left thoracotomy. In other patients unlikely to need an early descending intervention, a shorter "elephant trunk of convenience" is used. In these patients, we place a short invaginated elephant trunk into the descending aorta. We find that the turgor of this short trunk holds the aortic open nicely and facilitates the distal anastomosis.

The majority of patients (n = 458; 74.7%) underwent root-sparing aortic replacement, 149 (24.3%) had root replacement, and 6 (1%) had another procedure, such as patch repair, performed under DHCA. The distal arch anastomosis was sutured proximally to the left subclavian artery in most patients (n = 94; 75.2%). Most patients exhibited good perfusion of the left subclavian artery from flow outside the elephant trunk graft. Among those in whom the elephant trunk was occlusive, 8 patients underwent extra-anatomic subclavian artery bypass, and 2 patients required revascularization during follow-up. The head vessels were most commonly anastomosed as an island patch, and 49 (39.2%) patients had individual branch grafts. In patients who required a stage 2 elephant trunk procedure for the descending aorta, the left subclavian artery was revascularized from the new descending aortic graft.

The mean duration of DHCA was 29.7 ± 8.5 minutes (range, 10-62 minutes). The majority of patients had a DHCA duration of <40 minutes (n = 524; 85.5%); 19 patients (3.1%) had a DHCA duration of >50 minutes. The mean duration of DHCA was 26.6 ± 5.4 minutes (range, 10-50 minutes) for hemiarch replacements and 41.0 ± 7.5 minutes (range, 22-62 minutes) for total arch replacements (P = .000). Surgical data are presented in Table 2.

Follow-up

Follow-up on mortality was evaluated using the United States Social Security Death Index, the EpicCare electronic medical record database (which registers deaths occurring in the state of Connecticut), online obituaries, office visits, phone calls, and e-mails. Surviving patients were censored at the date of last clinical contact at Yale-New Haven Hospital, leading to 100% complete follow-up. Our strategy for follow-up has been described and analyzed previously.[7] The mean duration of clinical follow-up was 3.8 ± 3.4 years (range, 0-14.1 years), and the median duration of follow-up was 2.95 years. Only the reinterventions performed at Yale-New Haven Hospital could be accounted for.

Statistics

Statistical analysis was performed using SPSS version 21 (IBM, Armonk, New York). Continuous variables are represented as mean ± standard deviation (range), and categorical variables are presented as absolute values and percentages. Comparisons were conducted using an unpaired 2-tailed t test for continuous variables and the Pearson χ^2 test or Fisher exact test for categorical variables.

Survival was analyzed by Kaplan-Meier survival estimation, using log-rank, Tarone-Ware, and Breslow tests for comparisons. To compare the survival of the study group with that of a normal population, a reference