Totally Normothermic Aortic Arch Replacement Without Circulatory Arrest

Gilles D. Touati, MD, Nicolas Roux, MD, Doron Carmi, MD, Alexandra Degandt, MD, Amar Benamar, MD, Paul Marticho, MD, Alphonse Nzomvuama, MD, and Henri J. Poulain, MD

Departments of Cardiovascular Surgery and Anesthesiology, Centre Hospitalier et Universitaire d'Amiens, Amiens, France

The authors propose a new strategy of normothermic perfusion for replacement of the aortic arch to avoid the complications of profound hypothermic circulatory arrest. Six patients underwent complete replacement of the aortic arch under normothermia using two pumps for the body (one for the brain and the thoracoabdominal aortic branches) and one for the heart. The surgical procedure was performed with no time limit. There were no operative or late deaths. No patients had neurologic deficit and all were rapidly extubated with uneventful postoperative courses. The method preserves autoregulation of cerebral blood flow and maintains body perfusion without high vascular resistances.

(Ann Thorac Surg 2003;76:2115–7)

The fact that deep hypothermic circulatory arrest (25 minutes or more) and advanced age are associated with neuropsychological deficits [1], the morbidity induced by hypothermia, and especially the impossibility of reliably establishing an optimal cerebral blood flow indexed to perfusion temperature have encouraged the search for a new operative strategy.

In light of 6 cases, we propose a new approach to aortic arch replacement in which normothermic perfusion is maintained. This technique provides an increased safety and has enabled us to perform the aortic replacement more calmly, thereby allowing a more radical and more distal procedure on the isthmic aorta and avoiding a "hasty surgery" that could interfere with the quality of the repair.

Six patients underwent aortic arch replacement under normothermic conditions. The inclusion criteria were the presence of a lesion of the ascending aorta extending to the horizontal and an isthmic aorta, or both. Patients with obstructive carotid stenosis jeopardizing antegrade perfusion of the brain and those with preoperative neurologic impairment were excluded.

Median age of the patients was 57.6 ± 11 years (range, 40 to 72 years).

Specific operative monitoring included a rectal and esophageal temperature, a pressure monitoring of the right radial and left femoral artery, and a bi-spectral index of the brain activity.

Technique

Cardiopulmonary bypass was established between the right atrium and the right femoral artery. A second arterial line geared by a separated roller pump was used for the perfusion of the cerebral arteries (Fig 1). For this purpose, the truncus brachiocephalicus and the left common carotid artery were selectively cannulated using beveled cannulas (Foch Carotid Cannula Ref. 470035 and 470025 Polystan, Perouse Lab). A 3.5-mm cannula and a 2.5-mm cannula were used for the perfusion of the truncus brachiocephalicus and left common carotid artery, respectively. The cannulas were connected with a y-line to the second arterial line. Finally, a retrograde warm cardioplegia was delivered intermittently every 7 to 10 minutes through a third arterial line and pump. During the whole perfusion, the arterial pressure in the radial artery was maintained at approximately 70 mm Hg, and the arterial pressure in the femoral artery was maintained at approximately 55 mm Hg. The core temperature was maintained between 36°C and 37°C.

Specific features of our technique included an introduction of the cerebral perfusion cannulas 1 to 2 cm distal to their origin of the arch vessel to provide room for clamping, and an occlusion of the descending thoracic aorta either by insertion of a Robiscek Pruitt aortic occlusion catheter after opening the horizontal aorta (Ref. 12F-RPK Ideas for Medicine) or by direct clamping, which we did in 5 patients and 1 patient, respectively.

The surgical procedure was tailored according to the underlying disease and the extent of the lesions. A woven vascular prosthesis (Polythese, Perouse Lab) was used in all patients.

Results

No patient died and all woke without neurologic deficit. No transient or permanent neurologic deficit was observed. Cognitive function was preserved in all. Cardiac function was excellent in all. Cardiopulmonary bypass (CPB) was stopped without using inotropic drugs in all

Accepted for publication April 23, 2003.

Address reprint requests to Dr Touati, Department of Cardiovascular Surgery, Centre Hospitalier et Universitaire d'Amiens, Hôpital Sud 80054, Amiens Cedex 01, France; e-mail: gtouati.hms@invivo.edu.

Published by Elsevier Inc

0003-4975/03/$30.00
doi:10.1016/S0003-4975(03)00739-2

Ann Thorac Surg
2003;76:2115–7

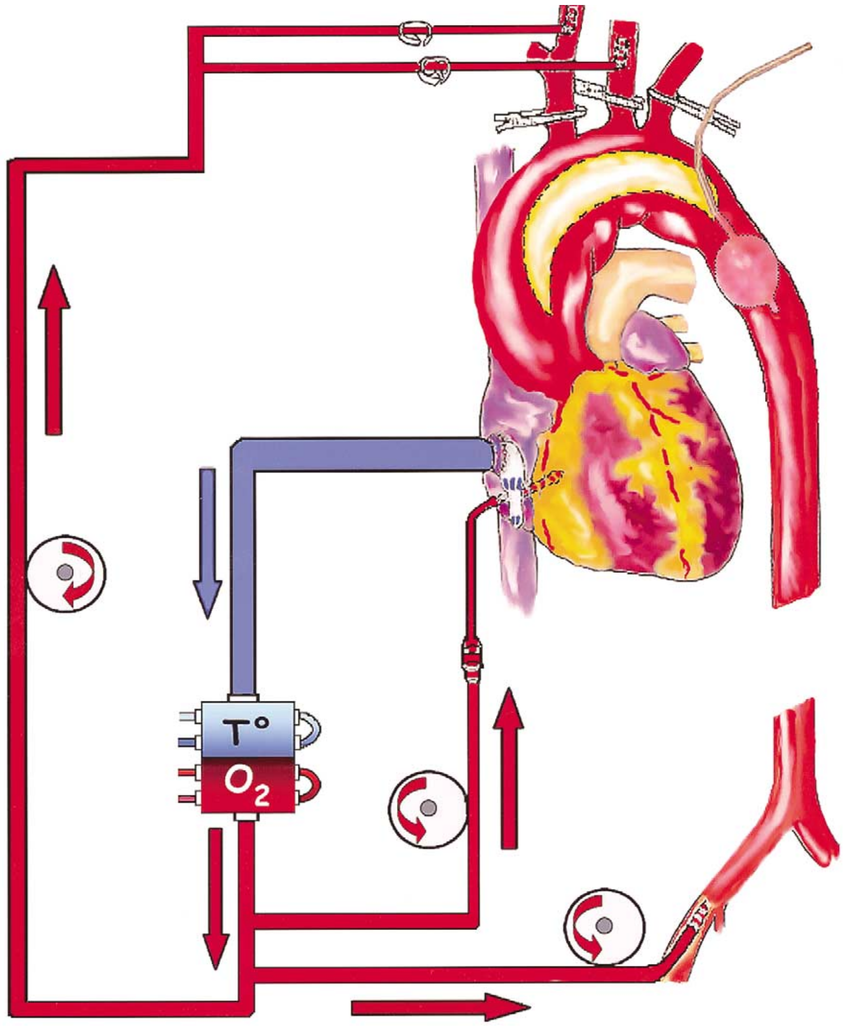

Fig 1. Schematic drawing of the cardiopulmonary bypass circuit with three separate arterial pumps for femoral artery, anterograde cerebroperfusion, and retrograde coronary perfusion. Descending aortic occlusion was obtained with a Robiscek-Pruitt aortic catheter.

patients. Postoperative mean ejection fraction was similar to preoperative values (52% vs 56.6%). Coagulopathy, hepatic or renal impairment did not occur. All patients were extubated between the 4th and 16th postoperative hour (median, 11 postoperative hours), and mean blood loss in the drains was 545 ± 105 mL on the first day. In order to maintain a perfusion pressure greater than or equal to 70 mm Hg in the right radial artery, cerebral circulation pump flow rates varied from 680 mL/min to 1,100 mL/min, indicating variable degrees of vasoplegia from one patient to another.

Comment

In view of the disadvantages of circulatory arrest with profound hypothermia, anterograde or retrograde selective perfusion, and the absence of any additional neurologic protective effect of hypothermic CPB compared with normothermic CPB [2], it seemed logical to propose a completely normothermic approach to aortic arch surgery.

This choice was guided by two elements: (1) the superiority of anterograde cerebral perfusion over retrograde perfusion [3] and the superiority of normothermic CPB over hypothermic CPB, as demonstrated by several published randomized studies [2, 4].

As hypothermia decreases, but does not eliminate cerebral metabolism [5], maintenance of cerebral perfusion appears to be essential.

Autoregulation of cerebral blood flow rate is partially maintained at a temperature of 20°C, but it is altered and largely compromised at temperatures less than 20°C because of an increase in the cerebral vascular resistances (339 ± 48%) [5]. A 30% reduction of the theoretical cerebral blood flow also induces loss of autoregulation properties [6]. Therefore anterograde cerebral perfusion between 6°C and 12°C seems to be potentially harmful with a risk of excessive or insufficient cerebral perfusion.

We prospectively decided to reproduce conditions strictly identical to those of the classic normothermic CPB, with intra-arterial blood pressure monitoring in all perfused territories. In our series with a fixed temperature of 37°C, the cerebral perfusion pump flow rate varied by a factor of 1 to 1.6 in order to maintain an identical perfusion pressure; opening of anatomical shunts, the state of systemic resistance, and maintenance of autoregulation are the main explanations for this variability. Therefore a fixed cerebral perfusion flow rate can induce excessive or insufficient cerebral blood flow depending on instantaneous vascular resistance.

Normothermic CPB and myocardial protection at 37°C have gradually become part of standard practice in many adults or pediatric surgical teams on the basis of the superior results obtained because of the maintenance of the patient's physiologic state. Simple application of this technique to aortic arch surgery should provide the same advantages and eliminate the adverse effects of hypothermia and circulatory arrest

A parallel can be drawn between myocardial protection and cerebral protection. With a time lag of 12 to 15 years, cerebral protection has advanced along similar lines (ie, no perfusion with profound hypothermia followed by hypothermic anterograde perfusion and then hypothermic retrograde perfusion). Normothermia appears to be the next logical step in cerebrospinal protection, allowing more physiologic autoregulation of cerebral blood flow.

Applications of this normothermic approach to the pediatric population could decrease long-term deficits in cognitive function.

We thank Dr René Prêtre, Division of Cardiac Surgery at the University of Zurich Hospital, Switzerland, for technical advice for this article.

References

1. Reich DL, Uysal S, Sliwinski M, et al. Neuropsychologic outcome after deep hypothermic circulatory arrest in adults. J Thorac Cardiovasc Surg 1999;117:156–63.
2. Grigore AM, Mathew J, Grocott HP, et al. Prospective randomized trial of normothermic versus hypothermic cardiopulmonary bypass on cognitive function after coronary artery bypass graft surgery. Anesthesiology 2001;95(5):1110–9.
3. Okita Y, Minatoya K, Tagusari O, et al. Prospective comparative study of brain protection in total aortic arch replacement: deep hypothermic circulatory arrest with retrograde cerebral perfusion or selective antegrade cerebral perfusion. Ann Thorac Surg 2001;72:72–9.
4. Grimm M, Czerny M, Baumer H, et al. Normothermic cardiopulmonary bypass is beneficial for cognitive brain function after coronary artery bypass grafting–a prospective randomized trial. Eur J Cardiothorac Surg 2000;18:270–5.
5. Tanaka J, Shiki K, Asou T, Yasui H, Tokunaga K. Cerebral autoregulation during deep hypothermic nonpulsatile cardiopulmonary bypass with selective cerebral perfusion in dogs. J Thorac Cardiovasc Surg 1988;95:124–32.
6. Dirnagl U, Pulsinelli W. Autoregulation of cerebral blood flow in experimental focal brain ischemia. J Cereb Blood Flow Metab 1990;10(3):327–36.