

Thoracoabdominal aortic aneurysm repair using hypothermic cardiopulmonary bypass and circulatory arrest

Nicholas T. Kouchoukos

Division of Cardiovascular and Thoracic Surgery, Missouri Baptist Medical Center, St. Louis, Missouri, USA

Corresponding to: Nicholas T. Kouchoukos, MD. 3009 N. Ballas Road, Suite 360C St. Louis, MO, 63131, USA. Email: ntkouch@aol.com.



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Introduction

Several options exist for the open surgical repair of thoracoabdominal aortic aneurysms. These include the “clamp and sew” technique, and use of distal perfusion with either partial (left-heart) bypass, or total cardiopulmonary bypass (CPB). Total CPB with an interval of hypothermic circulatory arrest is a widely used technique for operations on the ascending aorta and aortic arch. It is less commonly used for operations on the descending and thoracoabdominal aorta. However, when used in this setting, we believe it offers several advantages over other techniques (*Video 1*). It requires only minimal dissection of the periaortic tissues, eliminates the need for proximal and sequential aortic clamping, and provides easy access to the distal aortic arch. It provides a bloodless and quiet operative field when the circulation is arrested and permits return of all shed blood into the perfusion circuit. It also provides protection of the central nervous system, the heart, and the abdominal organs without the need for monitoring of evoked potentials or separate perfusion of the coronary, visceral, and renal arteries.

Operative technique

A catheter is inserted for continuous drainage of cerebrospinal fluid if technically feasible. After insertion of monitoring catheters, induction of anesthesia, and the placement of a double-lumen endotracheal tube, the patient is positioned in a right lateral decubitus position with the hips turned to the left at a 45° angle. A standard posterolateral thoracotomy incision is made either through the fifth or sixth intercostal space. If necessary, the incision

is extended into the abdomen across the costochondral junction and the diaphragm is incised circumferentially. Simultaneously, the left common femoral artery and vein are isolated through an oblique incision in the skin crease of the groin. Heparin is administered to achieve an activated clotting time of more than 400 sec. A long cannula (28-34 F) is inserted through the left common femoral vein, and the tip is positioned in the right atrium under transesophageal echocardiographic guidance. The femoral artery is cannulated with an 18 to 22 F short cannula. CPB is established, and cooling is initiated (target temperature, 15-17 °C). A catheter is preferentially placed through the left inferior pulmonary vein or through the apex of the left ventricle for venting of the left heart.

Since femoral artery perfusion might lead to the retrograde embolization of thrombus or atheroma into the cerebral circulation, we have modified our cannulation technique for patients with atherosclerotic disease and degenerative aneurysms. In addition to standard femoral artery cannulation, a dispersion arterial cannula (Edwards Lifesciences Inc., Midvale, UT, USA) is inserted directly into the descending thoracic aorta at a non-calcified, thrombus-free site identified by epiaortic ultrasonographic analysis. The aortic cannula and the femoral artery cannula are then connected to separate arterial lines from the pump oxygenator. In these patients, CPB is established using the arterial line attached to the aortic cannula, and the femoral line is clamped. Alternatively, a small left axillary incision is made and an 8-mm collagen-impregnated graft is anastomosed to the left axillary artery and used for proximal perfusion. The femoral arterial line remains clamped while the patient is cooled on CPB. In all other cases, particularly in the setting of aortic dissection, the femoral artery is used

to establish CPB.

During the period of cooling, methylprednisone (7 mg/kg) is administered intravenously, and the head is packed in ice. Cardioplegia is not induced, and somatosensory and motor evoked potentials are not monitored. When electroencephalographic silence is achieved and the nasopharyngeal temperature is 22 °C or lower, circulatory arrest is established. The diseased segment of aorta is incised and, if indicated, the incision is extended into the aortic arch. The left phrenic, left vagus and left recurrent nerves are identified and protected. A collagen-impregnated woven polyester aortic graft (26-32 mm) containing a 10 mm side arm (Hemashield Platinum single branch graft; MAQUET Cardiovascular LLC, San Jose, CA, USA) is sutured end-to-end to the transected descending thoracic aorta or aortic arch with a continuous 3-0 or 4-0 polypropylene suture buttressed with a strip of felt. As this suture line is completed, cold blood (10-12 °C) from the pump-oxygenator is infused retrogradely into the venous cannula to assist in the evacuation of air and debris from the upper circulation and from the graft. The side arm of the graft is attached to the proximal arterial line from the pump oxygenator. After evacuation of air, a clamp is placed on the graft just distal to the side arm, and flow to the upper body is reestablished at a rate of 15-20 mL/kg/min and a temperature of 20-22 °C (low-flow hypothermic bypass). Patent intercostal and lumbar arteries below the level of the sixth or seventh intercostal space are preserved when technically feasible using a full-thickness cuff of aorta that is sutured to an opening in the graft. The proximal clamp is subsequently repositioned on the graft below the anastomosis between the graft and the intercostal patch to permit perfusion of the implanted arteries.

When possible, a clamp is placed on the abdominal aorta below the level of the renal arteries to permit hypothermic perfusion of the lower body using the femoral artery cannula. Alternatively, the distal aorta (or a previously placed infrarenal aortic graft) is occluded with an intraluminal balloon-tipped catheter and flow to the lower body is established. The distal thoracic and upper abdominal aorta is then opened and the orifices of the celiac, superior mesenteric, and of the left and right renal arteries are identified. If the aortic disease extends to the level of the iliac arteries, a bifurcation graft (Hemashield Platinum bifurcation graft; MAQUET Cardiovascular LLC) is implanted, with each common iliac artery anastomosis performed using 5-0 polypropylene suture.

The visceral and renal arteries are separately reimplemented

using a collagen-impregnated woven polyester branched aortic graft (Hemashield Platinum TAAA graft; MAQUET Cardiovascular LLC). With this technique, these arteries are detached from the aorta with a small cuff of aortic tissue. If the origin of the vessel is severely stenotic, the vessel is transected beyond the stenosis. The body of the aortic graft is positioned so that the 3 contiguous branches lie opposite the origins of the celiac, superior mesenteric, and right renal arteries. The distal end of the aortic branched graft is cut to the appropriate length and sutured to the infrarenal aorta (or previously placed infrarenal aortic graft) with a continuous 3-0 or 4-0 polypropylene suture buttressed with a strip of felt. As the distal suture line is being completed, the clamp or balloon on the distal aorta is released to evacuate air and debris using femoral arterial perfusion.

A clamp is placed proximal to the distal suture line, and flow to the lower body is re-established. Thirty-five percent of the total arterial flow is directed through the proximal arterial line and 65% through the distal line. The temperature of the perfusate is adjusted to maintain the nasopharyngeal temperature between 20 and 22 °C, and total flow is maintained between 0.75-1.5 L/min/m². During this period of hypothermic low-flow, the anastomoses between the branches of the graft and the visceral and renal arteries are completed using 5-0 or 6-0 polypropylene sutures. Typically, the most distal branch is anastomosed to the right renal artery, followed by the middle limb to the superior mesenteric artery and the upper limb to the celiac artery. The left renal artery is either sewn to the fourth (perpendicular) branch or attached end-to-end to a separate 6-10 mm interposition graft. Direct perfusion of the renal and visceral arteries is not used. After each anastomosis is completed, the distal clamp on the aortic graft is positioned more proximally to enable perfusion of each reimplemented artery. Rewarming is initiated after establishing perfusion to both the implanted intercostal and renal arteries. The final anastomosis between the proximal aortic graft (with the 10 mm side arm) and the distal branched aortic graft is performed using a 4-0 polypropylene suture. Air is evacuated from the graft through multiple puncture sites created with an 18-gauge needle. Flow from the femoral arterial line is discontinued, the proximal clamp is removed, and full antegrade flow is established from the proximal arterial line. Spontaneous defibrillation usually occurs when the nasopharyngeal temperature reaches 26-28 °C. When the bladder temperature reaches 35 °C, the pulmonary vein venting catheter is removed and CPB is discontinued.

Comments

We have treated 243 patients with the technique we have described (1). These patients had Crawford extent I, II, and III thoracoabdominal aortic aneurysms. Patients with Crawford extent IV aneurysms were treated with other techniques. The 30-day mortality was 7.8 percent, and is comparable to that reported with other open and hybrid techniques. Spinal cord ischemic injury occurred in 5.3 percent of patients. Of importance, the 30-day mortality and spinal cord ischemic injury rates were significantly lower (5.6 percent and 3.9 percent, respectively) for the patients undergoing elective operation, than among the patients undergoing emergent operation (33.3 percent and 16.7 percent, respectively). The intraoperative transfusion of blood components was not excessive and did not exceed that reported for other open techniques.

In a multivariate analysis for the composite outcome of death, stroke, spinal cord ischemic injury and need for dialysis, emergent operation, increasing preoperative creatinine level, presence of coronary artery disease, and increasing duration of CPB emerged as significant risk factors (2).

Our experience, and that of others who have used this technique extensively, indicates that hypothermic CPB with an interval of circulatory arrest is a safe technique for operations on the thoracoabdominal aorta (1-3). It provides

substantial protection against paralysis, and against renal, cardiac, brain and visceral organ dysfunction that equals or exceeds that provided by other currently utilized techniques. Routine use of this technique for the management of extensive aortic disease that requires lateral exposure is justified, and remains our technique of choice.

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