Distal Aortic Perfusion and Selective Visceral Perfusion

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Contents

13.1 Introduction .............................................. 141
13.2 Operative Technique and Adjuncts .................. 142
  13.2.1 Cerebrospinal Fluid Drainage ................. 142
  13.2.2 Thoracoabdominal Incision ................... 143
  13.2.3 Diaphragm Preservation ....................... 143
  13.2.4 Distal Aortic Perfusion ....................... 143
  13.2.5 Sequential Cross-Clamping ................. 144
  13.2.6 Reattachment of Intercostal Arteries .... 144
  13.2.7 Visceral and Renal Perfusion ............... 146
13.3 Impact of Adjuncts on Outcome ................... 147
  13.3.1 Neurological Deficit: Immediate and Delayed .... 147
  13.3.2 Renal Failure ................................ 148
  13.3.3 Aortic Dissection ............................ 149
13.4 Summary .............................................. 149

13.1 Introduction

Thoracoabdominal aortic aneurysm repair was first performed by Etheredge [1] in 1955. Using a temporary shunt to divert blood flow from the distal thoracic aorta to the distal abdominal aorta, Etheredge excised a thoracoabdominal aortic aneurysm and restored blood flow by inserting a homograft tube. De Bakey reported a similar shunt and homograft technique in 1956. Later that year, De Bakey [2] began to use a Dacron tube graft that was sewn to the descending thoracic aorta and infrarenal abdominal aorta, and sequentially performed separate bypass grafts of the celiac, superior mesenteric and both renal arteries. This became the mainstay of thoracoabdominal aortic aneurysm repair in its new beginning, because of its relative simplicity and reduced ischemic insult to the viscera and kidneys. In 1965, Crawford and the Baylor group then started to set the standard in thoracoabdominal aortic surgery, as they recruited large volumes of patients. Crawford’s technique stemmed primarily from the early works of Matas and Carrell, and encompassed three basic principles of aortic surgery: the inclusion technique, use of a Dacron tube graft conduit, and reimplantation of visceral and renal arteries. In 1888, Matas [3] had first repaired an aneurysm of the brachial artery within the walls of the aneurysm, an inclusion technique later termed as endoaneurysmorrhaphy. On the other hand, direct reattachment of visceral arteries to a hole made in the prosthetic graft was pioneered by Carrell [4], who had experimented with different methods for reattaching smaller vessels to larger ones, at the turn of the twentieth century. Creech [5] reported his approach for thoracoabdominal aortic aneurysm repair, in 1966. Thoracoabdominal aortic repair in this early time, however, was still very arduous, an extremely lengthy procedure, and associated with severe ischemia of the spinal cord, viscera and kidneys.

Connolly et al. [6] of Irvine, California, were the first to use the pulsatile left heart bypass as an adjunct for repair of the descending thoracic aneurysm. Korompai [7], at Scott and White Clinic in Temple, used an ingenious method to perfuse the viscera, by diverting blood from the descending thoracic aorta via a branched cannula connected to the celiac axis, superior mesenteric and both renal arteries. In the mid-1970s, after trying out various adjuncts, Crawford et al. [8] settled on the clamp-and-go technique, because this simplified the procedure, shortened the length of the operation and produced good results. The modern era of repair of thoracoabdominal aortic aneurysm was then ushered in. However, high rates of postoperative paraplegia remained, and adjuncts continued to be explored widely into the 1980s.

The original experimental work of Spencer, Cunningham, Laschinger and others at John Hopkins University enlightened the surgical community to the significance of intercostal artery reattachment in thoracoabdominal aortic repair. Subsequently, Cunningham et al. [9, 10] proposed the combined use of distal aortic perfusion and somatosensory-evoked potential (SSEP) to identify the artery of Adamkiewicz. In contrast, Crawford et al. [11] reported high rates of false positives and false negatives in SSEP changes when correlated with postoperative neurological deficit. In 1988, Hollier [12], while at the Mayo Clinic, established the use of perioperative ce-
Rebrosplinal fluid (CSF) drainage, and reported a dramatic reduction in the incidence of paraplegia. In a subsequent randomized clinical trial, Crawford et al. [13] showed that CSF drainage provided no significant benefit; however, intraoperative CSF drainage was allowed only up to 50 mL, and this limitation may have been the reason for the negative result of their study. Because adjuncts had been up to now largely unsatisfactory, protection of the spinal cord by simply reducing the aortic cross-clamp time became the focus. To minimize the ischemic time to aortic segments, sequential clamping of the aorta was essential to the clamp-and-go technique. Also during this period, the classification of the extent of thoracoabdominal aortic aneurysms (Fig. 13.1) was solidified, to permit meaningful comparisons between various surgical groups and methods [14].

The 1990s were characterized by further experiments with adjuncts, and different centers concentrated on different techniques, including hypothermia [15, 16] and regional spinal cord cooling [17]. Crawford’s cumulative work was reviewed by Svensson et al. [18] in a landmark paper published in 1993. The incidence of neurological deficit was correlated with the extent of aneurysm, clamp time, rupture, age, proximal aortic aneurysm and renal dysfunction [18]. Simple clamp-and-go technique was virtually abandoned [16, 17, 19]. In 1992, after several years of animal experiments and promising clinical results reported by ourselves and other investigators, we adopted the combined adjunct distal aortic perfusion and CSF drainage for all patients undergoing thoracoabdominal aortic repair [19, 20]. We then observed considerable improvement in patient outcome. In this chapter, we will discuss the adjuncts of distal aortic perfusion, CSF drainage, moderate hypothermia and visceral perfusion, and review their impact on neurological deficits and organ protection.

### 13.2 Operative Technique and Adjuncts

The patient is brought to the operating room and placed in the supine position on the operating table and prepared for surgery. The right radial artery is cannulated for continuous arterial pressure monitoring. General anesthesia is induced. Endotracheal intubation of the patient is established using a double lumen tube for selective right lung ventilation during surgery. A sheath is inserted in the internal jugular vein, and a Swan-Ganz catheter is floated into the pulmonary artery for continuous monitoring of the central venous and pulmonary artery pressures. Large-bore central and peripheral venous lines are established for fluid and blood replacement therapy. Temperature probes are placed in the patient’s nasopharynx and bladder (or rectum). Electrodes are attached to the scalp for an electroencephalogram (EEG) and along the spinal cord for SSEP to assess the central nervous system and spinal cord function, respectively. Although a detailed account of the essential anesthetic care during thoracoabdominal aortic repair is beyond the scope of this chapter, the importance of adequate maintenance of systemic arterial pressure with judicious blood transfusion cannot be overemphasized, as perfusion of vital organs depends on the systemic pressure.

#### 13.2.1 Cerebrospinal Fluid Drainage

When the descending thoracic aorta is cross-clamped, the spinal cord is rendered ischemic because of decreased perfusion to the spinal cord and consequent increased CSF pressure. The rationale for our use of CSF drainage is to increase the spinal cord perfusion pressure directly with distal aortic perfusion, and indirectly by reducing CSF pressure. Once all catheters, probes

**Fig. 13.1.** Thoracoabdominal aortic aneurysm classification. Extent I, distal to the left subclavian artery to above the renal arteries. Extent II, distal to the left subclavian artery to below the renal arteries. Extent III, from the sixth intercostal space to below the renal arteries. Extent IV, from the 12th intercostal space to the iliac bifurcation (total abdominal aorta). The original Crawford classification comprises extent I to extent IV. We have since added extent V, from below the sixth intercostal space to above the renal arteries.

**Fig. 13.2.** Placement of the lumbar catheter in the third or fourth lumbar space to provide cerebrospinal fluid drainage and pressure monitoring.