Neuroprotection Strategies in Aortic Surgery

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KEYWORDS

• Neuroprotection • Neurologic monitoring • Brain oximetry • Near-infrared spectroscopy • Deep hypothermic circulatory arrest • Circulatory arrest • Antegrade cerebral perfusion • Retrograde cerebral perfusion

KEY POINTS

- Common modalities of neuromonitoring used in aortic arch surgery are electroencephalography (EEG), peripheral somatosensory-evoked potentials (SEPs), and cerebral oximetry by near-infrared spectroscopy (NIRS).
- Selective antegrade cerebral perfusion (sACP) typically involves cannulation of the right innominate or axillary artery with simultaneous clamping of the more proximal innominate artery. The resulting cerebral blood flow (CBF) is via the right carotid artery, whereas the remainder of the body undergoes circulatory arrest. An intact circle of Willis is mandated for the unilaterally antegrade cannulated innominate or axillary artery to provide contralateral cerebral hemisphere flow.
- Adjunctive cerebral perfusion results in adequate brain protection at more moderate hypothermic temperatures resulting in decreased hypothermia-related coagulopathy, decreased cardiopulmonary bypass (CPB) times, decreased renal dysfunction, and decreased hypothermia-related neuronal injury.
- Two acid-base management strategies exist, alpha stat and pH stat. Each offers distinct advantages and is implemented during particular stages of hypothermic CPB.
- The benefits associated with inducing lower body circulatory arrest at more moderate degrees of hypothermia will likely continue the current trend of increasing moderate hypothermic circulatory arrest (MHCA) with sACP adoption.

INTRODUCTION

Surgical therapy for aortic arch dissections and aneurysms involves partial or complete replacement of the aortic arch. Intervention requires anatomic-specific consideration for the aorta and its affected organ systems, specifically, the potential for neurologic risks or perioperative effects. Neurologic protection during aortic arch surgery is challenging due to the 3 branches from the aortic arch giving rise to the vessels completely

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responsible for brain perfusion. Nervous tissue is particularly at risk during aortic procedures due to its high metabolic demand and dependence on aerobic metabolism. The potential for devastating, and potentially irreversible, neurologic-related morbidity resulting from ischemic injury to the brain and spinal cord mandates that neuroprotection is the principal concern during circulatory management in aortic surgery. The entire spectrum of neurologic injury, from transient paresis to stroke or paraplegia, is possible in aortic surgery. Hemiarch and total aortic arch replacements necessitate an open distal anastomosis and circulatory arrest. This requirement results in either ischemic visceral beds, or at least a decreased level of perfusion perioperatively. As a result, strategies have been developed to minimize neurologic injury from hypoperfusion and to lengthen circulatory arrest times while maintaining a margin of safety. These strategies include pharmacologic adjuncts, hypothermic circulatory arrest (HCA), antegrade cerebral perfusion (ACP), and retrograde cerebral perfusion (RCP). Monitoring is a key component of surgery, both intraoperatively and postoperatively, for optimal outcomes.

This review discusses the methods of neuroprotection during aortic arch procedures. These involve pharmacology, cooling, neuromonitoring, and circulatory and cannulation management strategies, allowing for actively manipulating CBF to circulatory arrest, rewarming, and acid-base management.

PROCEDURAL OF RISKS

Diseases of the ascending and aortic arch include acute aortic dissection to chronic aneurysmal disease. Aortic arch surgery, when performed for these diseases, puts patients at multiple risks. Although this review focuses on neurologic risks (Table 1), the risks of myocardial infarction, perioperative respiratory insufficiency, and renal dysfunction are also common. The disease process combined with the surgical repair of aortic arch diseases may involve any component of the circulation, resulting in potential visceral bed malperfusion to the heart, brain, spinal cord, kidneys, gastrointestinal tract, and extremities. Because current trends are for aortic repairs performed at more moderate temperatures that may mitigate theoretic systemic complications of deeper hypothermia (ie, renal dysfunction and bleeding complications), adjuncts must be incorporated to maintain or decrease current neurologic risk profiles. Prolonged CPB time is a risk factor for the development of bilateral watershed strokes, perhaps the result of increased

Table 1
Independent predictors of neurologic dysfunction specific to arch and ascending aorta surgery.

Stroke	Temporary Neurologic Dysfunction
Age (>60 y old)	Age
Female	Prior stroke/TIA
History of cerebrovascular disease	History of central neurologic event
New preoperative neurologic symptoms	Estimated GFR <90 mL/min
Hypertension	Emergency operation status
Diabetes	Acute type A dissection
Chronic obstructive pulmonary disease	Proximal aortic surgery
Previous aortic surgery distal to the left subclavian artery	Duration of cardiac arrest
Emergency operation status	Total cerebral protection time
Acute type A dissection	Concomitant cardiac procedures (ie, coronary artery bypass grafting)
Operation intended for the arch (including total arch replacement)	Red blood cell transfusion
Descending aortic aneurysm containing clot/atheroma	
General presence of clot/atheroma in aorta	
CPB time	
Duration of cardiac arrest	
Total cerebral protection time	
History of cerebral infarction or transient ischemic attack	
Concomitant cardiac procedures (ie, mitral valve replacement)	

Abbreviations: GFR, glomerular filtration rate; TIA, transient ischemic attack.