Aortic Arch Pathology
Surgical Options for the Aortic Arch Replacement

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KEYWORDS

• Aortic arch • Aortic arch pathology • Ischemia • Aortic arch repair • Graft • Aortic arch surgery

KEY POINTS

- Aortic arch surgery remains one of the most technically challenging procedures in cardiac surgery.
- Arch surgery demands consideration of myocardial, brain, spinal cord, visceral organs and lower body protection.
- A better understanding of the effects of brain and systemic ischemia during circulatory arrest, refinements in brain and end-organ protection, use of antegrade cerebral perfusion and moderate hypothermia have made arch repair safer.
- Novel surgical approaches have revolutionized arch surgery.
- As endovascular technology and open surgical techniques evolve, aortic surgeons learn and incorporate these methods into routine practice.

INTRODUCTION

Intervention of the aortic arch remains one of the more technically challenging procedures in cardiac surgery. These procedures demand consideration of not only myocardial protection, but also brain protection, spinal cord, and the lower body. This article discusses the anatomic, pathologic, diagnostic, and procedural considerations applicable to optimal care for aortic arch patients.

ANATOMIC CONSIDERATIONS

The aortic arch, also called the transverse aortic arch, is the segment of the aorta providing the origins of the brachiocephalic vessels. The usual anatomy of the left-sided arch includes, from proximal to distal, the origin of the innominate or the brachiocephalic artery, which splits into the right subclavian and common carotid arteries, followed by the left common carotid and finally the left subclavian artery. Important anomalies can affect the operative approach and must be recognized. The bovine arch is defined by the left common carotid arising from the innominate artery, and the vertebral artery can arise from the greater curve of the arch between the left common carotid and left subclavian arteries. Another common variation is called the anomalous right subclavian artery, commonly referred to as a Kommerrell's diverticulum. Careful review and understanding of the patient's anatomy and anomalies have to be taken into account for operative planning execution.

CLASSIFICATION OF AORTIC ARCH PATHOLOGY

For the consideration of surgical repair, aortic arch pathology can be broadly categorized into

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arch aneurysm, acute or chronic dissection, penetrating ulcer, and intramural hematoma.

Aortic arch aneurysms are the most common arch pathology encountered by surgeons, which can be caused by a variety of conditions (Table 1). Arch aneurysms overall represent about 10% of the aneurysms involving the thoracic aorta. These are most commonly caused by chronic aortic dissection (53%), followed by atherosclerosis (29%), and all other etiologies (19%).[1] As such, most of the data available regarding treatment indications and outcomes are drawn from patients affected by chronic dissection with aneurysmal degeneration of the arch. Other causative factors include genetically triggered connective tissue diseases, infection, and trauma (see Table 1). Isolated aortic arch aneurysms, presenting as localized saccular outpouchings of the arch are quite uncommon. Most of the arch aneurysms involve the contiguous segments of the aorta including ascending and or descending thoracic aorta.

Intramural hematoma, penetrating ulcer, and aortic dissection are a heterogeneous subset with the potential for evolution from one into another and represent the minority of arch disease.

DIAGNOSIS AND ASSESSMENT OF THE AORTIC ARCH PATHOLOGY

Aortic aneurysm is generally defined as permanent dilation of a segment of aorta that is at least 50% greater than its normal diameter. In healthy adults, aortic diameters usually do not exceed 40 mm at the root, which is the largest segment of the vessel. The aorta then gradually tapers distally and its size is influenced by a variety of factors including age, sex, height, weight, and blood pressure.[2–5] Aging is associated with a physiologic rate of enlargement of 0.9 mm in men and 0.7 mm in women, every decade.[4]

Most arch aneurysms are asymptomatic and, as such, are usually discovered incidentally. However, patients with arch aneurysm can present with compressive symptoms to adjacent organs such as hoarseness, dysphagia, lower respiratory tract infections, chest pain, and upper body edema (superior vena cava syndrome). Dissections involving the aortic arch can present with symptoms of brain malperfusion such as syncope, transient ischemic attack, or stroke.

When suspecting aortic arch pathology, the assessment of each patient should be aimed at understanding the lamented complaints, interpreting physical findings that may suggest impaired perfusion such as asymmetric brachiocephalic and distal pulses, and an abnormal neurologic examination. Ascertaining an individual cardiovascular risk profile and gathering a family history of aneurysms or dissections and sudden death are tantamount for assessing need for aggressiveness of intervention. From this global evaluation, the physician will determine the pretest probability for the presence of arch pathology and, therefore, will select the most appropriate test to probe the initial working diagnosis.

Imaging remains the primary diagnostic tool for arch pathology. In particular, the preferred modality allows the visualization of the entire aorta in a comprehensive manner. Precise measurement of aortic arch aneurysm diameter can be challenging because the axial images through the aortic arch produce an oblong rather than a circular contour (Fig. 1). Furthermore, measuring the long axis contour is misleading because this does not truly represent the aortic arch aortic diameter.

From the imaging standpoint, a few key points need to be emphasized (see Fig. 1; Fig. 2):

1. The aortic arch is a complex, 3-dimensional structure; therefore, a standardized measurement technique is critical to detect true

Table 1
Etiology of aortic arch aneurysm

Etiology	Defect	Disease
Degenerative	Cystic medial degeneration	Atherosclerosis
	Spontaneous rupture of vasa vasora or atherosclerotic plaque	Intramural hematoma
	Ulceration of arteriosclerotic plaque	Penetrating arteriosclerotic ulcer
Connective tissue disorder	FNB1 gene mutation	Marfan syndrome
	TGFβ receptor 1 and 2, TGFβ, and SMAD gene mutations	Loeys-Dietz syndrome (type 1–4)
	Type III collagen synthesis	Ehlers-Danlos type IV
Infected	*Staphylococcus aureus, S epidermidis, Salmonella, Treponemapallidum*	Mycotic aneurysm