Diagnostic and Treatment Dilemmas of the Aortic Arch

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KEYWORDS

• Aortic arch • Aortic aneurysm • Endovascular • Thoracic stent graft

KEY POINTS

- The aortic arch remains the last frontier for endovascular treatment, with unique anatomic and hemodynamic features posing special challenges to safe, durable repairs.
- Although total endovascular options for treatment of aortic arch abnormality are on the horizon of commercial availability, outcomes are subject to heterogeneity of studies and limited data.
- High-volume centers with aortic expertise continue to report improving outcomes for open aortic arch repair, the standard against which hybrid repair should be judged in both the short and the long term.

INTRODUCTION

The history of surgical repair of aortic arch aneurysms has been marked by improvements in anesthetic, surgical, and neuroprotective techniques. However, it remains an operation with the potential for significant morbidity and mortality, due to the physiologic and neurologic effects associated with cardiopulmonary bypass (CPB) and deep hypothermic circulatory arrest (DHCA). In addition, patients with aortic arch abnormalities often have features that increase surgical risk, such as advanced age, systemic comorbidities, or prior sternotomy, particularly with arch aneurysms after repair of an acute aortic dissection. Although case reports of surgical aortic arch repair without DHCA and CPB have been presented,[1–3] endovascular approaches are appealing for their minimally invasive nature, in addition to minimization or avoidance of CPB and DHCA.

The goals of endovascular repair of arch aneurysms are to completely exclude the aneurysm sac, avoid atheroemboli, and preserve perfusion of the supra-aortic branches. Unique anatomic and hemodynamic features of the arch pose special challenges to achieving these goals (Table 1).

Curvature and Angulation

An underlying principle for durability of endovascular stent grafting is the presence of a seal zone that has healthy aorta free of calcification and thrombus, parallel walls or minimal tapering, angulation less than 60°, and adequate length. Without these optimal conditions, proximal seal and stent conformity are imperfect and subject to compromise of long-term integrity. Furthermore, the dynamic strain of the arch curvature can lead to stent complications, such as migration, kinking, or fracture. Ishimaru zones 1 and 2 rarely meet the conditions for an ideal landing zone, necessitating a strategy for either extra-anatomic bypass, or fenestrated or multibranched graft procedures.

The authors have no financial interests to disclose.

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Cardiol Clin 35 (2017) 347–355
http://dx.doi.org/10.1016/j.ccl.2017.03.012

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Table 1
Unique characteristics of the aortic arch

Factor	Endovascular Concerns
Arch curvature	Trackability and conformity Endograft apposition, seal
Greater pulsatility and flow, dynamic strain	Risk of stent migration, kinking, or fracture Windsock movement of endograft before fixation
Supra-aortic branching	Cerebrovascular perfusion Landing zone limitations
Procedural	Atheroemboli, vascular injury, retrograde type A dissection

Hemodynamic Load

Compared with the descending thoracic and abdominal portions of the aorta, the aortic arch has greater pulsatility and higher blood flow. Pulsatile strain can occur in both the longitudinal and the circumferential directions but is theorized to be greater in the longitudinal direction, explaining the aortic elongation seen with aging.[4] The supra-aortic branches have relatively lower pulsatility, due to tethering to other anatomic structures. These hemodynamic factors have implications for long-term stent performance, including disconnection of modular devices.

Supra-aortic Branching

In addition to the challenges posed by arch curvature, the proximity of the branch vessel ostia is a major factor in evaluating Ishimaru zones 1 and 2 as adequate landing zones (**Fig. 1**A). The catastrophic consequences of covering the origin of a supra-aortic branch mandate precision in alignment and deployment. Bergeron and colleagues[5] have proposed an alternate classification scheme of landing zones relative to these ostia (**Fig. 1**B). Throughout the remainder of the discussion, the Ishimaru classification will be used.

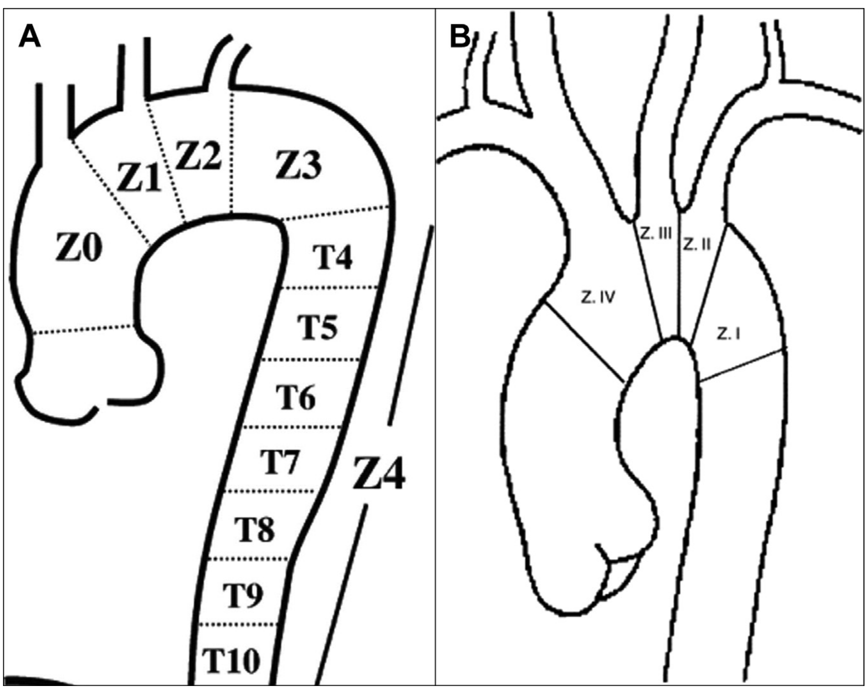

Fig. 1. (*A*) Anatomy of the aortic arch with Ishimaru classification of landing zones. Zone 0, ascending aorta up to the brachiocephalic artery; zone 1, between the brachiocephalic artery and LCCA; zone 2, between the LCCA and LSCA; zone 3, proximal descending thoracic aorta distal to LSCA; zone 4, middescending thoracic aorta. (*B*) Retrograde landing zone classification proposed by Bergeron, with zone 1 distal to LSCA; zone 2 lies between the LSCA and LCCA; zone 3 between the LCCA and innominate artery; zone 4 is the ascending aorta up to the brachiocephalic artery. (*From* Moon MC, Morales JP, Greenberg RK. The aortic arch and ascending aorta: are they within the endovascular realm? Semin Vasc Surg 2007;20(2):103; and Bergeron P, Mangialardi N, Costa P, et al. Great vessel management for endovascular exclusion of aortic arch aneurysms and dissections. Eur J Vasc Endovasc Surg 2006;32(1):41, with permission.)