Evolution of Thoracic Aortic Operations

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Tremendous innovations have been introduced in the last half-century to improve care for patients with aortic disease. Lesions that were essentially untreatable in the early 1950s can now be repaired with a greater likelihood of survival than ever imagined. Aortic repair has grown to encompass adjuncts designed to ameliorate specific surgical morbidities, such as cerebral, spinal cord, and renal ischemia, while embracing endovascular technologies to enable less invasive approaches, including hybrid procedures. Other recent technical advances include the use of prefabricated branched aortic grafts to minimize residual native aortic tissue and, thus, to reduce the late formation of patch aneurysms; surgical adhesives to improve the strength of fragile anastomoses; and valve-sparing aortic root replacement surgery to preserve the native aortic valve, improve hemodynamics, and reduce the need for anticoagulation. The evolution of surgical repair of the two most challenging aortic segments—the aortic arch and thoracoabdominal aorta—warrant detailed consideration.

Evolution of Aortic Arch Repair

The aortic arch has been particularly challenging to repair, more so than other sections of the aorta, largely because one must somehow interrupt the natural flow of blood to both the brain and downstream organs. In the mid-1950s, several attempts were made by surgeons to fully replace the aortic arch. In 1955, Cooley, Mahaffey, and DeBakey utilized emerging technologies, such as bypass shunts and hypothermia, in an ultimately unsuccessful attempt at arch repair [1]. It was not until another emerging technique, cardiopulmonary bypass, was added that DeBakey and colleagues were able to replace the aortic arch successfully [2]. The next major advance was the development of the hypothermic circulatory arrest technique, which enhanced the safety of arch replacement procedures. Subsequent advances focused on improving brain protection during the period of circulatory arrest; these advances included innovative approaches to perfusing and monitoring the brain [3, 4].

Now, in the 21st century, the same innovative spirit is being used to repair the aortic arch with endovascular techniques. Current options for aortic arch repair have grown to encompass several distinct endovascular strategies, from using single-branched endovascular devices designed to incorporate the left subclavian artery, to performing brachiocephalic debranching before placing standard tube stent-grafts, to the possibility of using triple-branched or triple-fenestrated stent-grafts to repair the aortic arch [5-15]. The main benefit—or, at least, perceived benefit—of these hybrid approaches is reduced short-term mortality and morbidity. The primary drawback of these hybrid approaches continues to be the substantial risk of stroke due to manipulation within the aortic arch, as well as the uncertain long-term functionality and durability of endovascular devices. However, the
continued exploration of hybrid approaches to aortic repair presents a tremendous opportunity to improve treatment and quality of life for patients with aortic arch disease.

**Evolution of Thoracoabdominal Aortic Repair**

Open surgical repair of thoracoabdominal aortic aneurysms (TAAAs) has traditionally involved greater operative risk than repairs of aneurysms in other aortic segments, and as was true in the early pioneering days of aortic surgery, TAAA repair remains a formidable challenge. With an approach similar to DeBakey and Cooley’s 1953 homograft repairs of the descending and abdominal aorta [16, 17], the first TAAA repairs were reported in 1955 by Etheredge and colleagues and by Rob [18, 19]. In 1965, DeBakey and colleagues [20] reported 42 cases of TAAA resection and described placing a Dacron graft extra-anatomically by creating end-to-side anastomoses before completely extirpating the aneurysm. Twenty years after joining DeBakey in Houston, Crawford [21] reported his evolving experience with 23 TAAA repairs. Drawing from techniques used in other surgical applications—anatomic endovascular graft inclusion, reimplantation of lumbar or intercostal arteries, and reattachment of the celiac axis and the superior mesenteric and renal arteries by direct suture of the vessel orifice to openings made in the graft, Crawford achieved a 96% survival rate, essentially setting a gold standard for all future comparisons. Despite this remarkable achievement, the need for continued development and refinement of treatment strategies persists as our population ages and confounding comorbidities increase. Patients who undergo replacement of the entire thoracoabdominal aorta (Crawford extent II) continue to exhibit the highest rates of early death, spinal cord deficit, and renal failure [22]. Most centers use a multimodal approach to minimize mortality and morbidity [23, 24, 25]. Common components of treatment strategies include cerebrospinal fluid drainage, distal aortic perfusion, and renal hypothermia [26-30].

However, the inherent risk of surgical repair has made endovascular approaches particularly attractive. Broadly speaking, stent-grafts can be used to treat TAAAs by either a purely endovascular approach or a hybrid approach, which combines aspects of endovascular and surgical repair. In the largely experimental purely endovascular approach, the entire repair is performed endoluminally through peripheral arterial access sites, and a custom-made device is usually used [31-35]. In contrast, a hybrid approach uses surgical procedures to reroute visceral circulation and thus enable placement of a simple, readily available tube stent-graft to exclude the aortic aneurysm [36-39]. For endovascular treatment to gain ground in the treatment of TAAAs, significant progress must be clearly demonstrated in the evolution of both design and implementation, the accumulation of patient-years of follow-up, and the development of guidelines for appropriate patient selection. Additionally, endovascular procedures must be associated with mortality and morbidity rates equal to or lower than those of open surgical repair. In the immediate future, open surgical repair of TAAA will continue to be the treatment of choice.

**Future Advances**

The future of aortic surgery will undoubtedly be heavily influenced by advancements in multiple disciplines_genetics, cellular biology, biochemistry, engineering, and bioinformatics_as well as by innovations in imaging, anesthesia, and surgical and endovascular technology. Personalized medicine will require surgeons to tailor...
treatments to the needs of individual patients and to be equally facile with both surgical and endovascular approaches. Anesthesia, universal to surgical and endovascular repair, will be guided by a thorough preoperative assessment of existing comorbidities, as well as any identified genetic or atherosclerotic risk factors, such that perioperative anesthetic strategy is specifically targeted [40]. Existing and emerging monitoring technologies, biomarkers, intraoperative transesophageal echocardiography (TEE), somatosensory evoked potentials (SEP), or muscle motor evoked potentials (MEP), will be used liberally to identify perioperative complications as they occur so that corrective measures can be implemented immediately.

REFERENCES