

Training the next generation in complex aortic surgery: needs and challenges

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Introduction

The increasing complexity of aortic disease management demands a new generation of surgeons who are equally fluent in open and endovascular therapies, skilled in multidisciplinary decision-making, and prepared to master the rapidly evolving technologies that underpin modern aortic practice. As training pathways diversify and case volumes shift, our profession must adapt its educational structures to ensure that future surgeons can deliver the highest-quality care to patients with complex aortic pathology.

Aortic surgery exists at the intersection of vascular and cardiothoracic practice, yet traditional training pathways have remained siloed. However, several recent developments present potential training solutions. One example is the pathway in which trainees complete an integrated vascular surgery residency before entering a traditional thoracic surgery fellowship. This route offers trainees exposure to endovascular techniques, open vascular reconstruction, and cardiothoracic operative principles in sequence, culminating in a hybrid skillset increasingly relevant to modern aortic surgery (1). Such trainees enter cardiothoracic fellowship with advanced wire skills, experience managing complex vascular pathology, a mature

understanding of aortic pathology, advanced management of cardiopulmonary bypass and advanced perfusion strategies (including left heart bypass and circulatory arrest), and the endovascular tools used to approach repair—attributes that directly support excellence in aortic procedures, including structural heart procedures. There are several variations of such training paradigms, including integration of vascular surgery with general surgery, cardiac surgery, and cardiothoracic surgery, with some trainees pursuing dual board certification in vascular surgery and thoracic surgery to better support aortic practice. Alternative modes of training include an apprenticeship model, in which trainees develop advanced aortic expertise through longitudinal mentorship within high-volume practices under the guidance of experienced surgeons.

The rationale for combining elements of vascular and cardiac training is not new; early pioneers of cardiovascular surgery routinely performed both peripheral and cardiac procedures. In fact, the most legendary aortic surgeon of his era, E. Stanley Crawford, served in several vascular societies and was instrumental in formalizing dedicated vascular surgical training within cardiovascular surgery (2). Modern training may benefit from returning to this broader conception of cardiovascular surgery within a single discipline. Many cardiothoracic programs have

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relatively limited exposure to aortic surgery, resulting in insufficient training to develop comfort with complex aortic interventions. Mastery of myocardial protection, mitigation procedures for malperfusion related to acute aortic dissection, cerebral perfusion strategies during hypothermic circulatory arrest as part of open arch repair, and the array of organ-protection strategies during open thoracoabdominal repair are fundamental to the training of a modern cardioaortic surgeon.

The case for expanded, integrated training has grown stronger as endovascular innovations have reshaped the field. The development of fenestrated and branched endograft technology has revolutionized thoracoabdominal and arch repair, but training exposure to these devices remains inconsistent across institutions. In the United States, access to fenestrated and branched endograft technology is further constrained by investigational device exemption regulations, which limit device availability to a few high-volume centers and contribute to uneven training exposure across institutions (3). Thus, despite rapid innovation, meaningful exposure to complex endovascular techniques remains concentrated in a small number of centers, creating a disconnect between evolving technology and trainee experience. Notably, there are relatively few high-volume aortic fellowships. Such fellowships include those provided at the University of Pennsylvania, University of Michigan, Baylor College of Medicine/The Texas Heart Institute, UTHealth Houston, Duke University, Cleveland Clinic, Mayo Clinic, and the University of Alabama at Birmingham, all of which offer comprehensive exposure to both open and complex endovascular aortic surgery.

In contrast, there are European super-fellowships that offer immersive experience in centerline planning, fusion imaging, branched and fenestrated device deployment, and multidisciplinary aortic team workflows. They also underscore the imbalance in U.S. training: despite steady expansion of endovascular options, access to high-complexity cases remains concentrated in relatively few institutions. The right candidates for these advanced training experiences share several attributes: strong foundational wire and catheter skills, technical facility with open vascular procedures, and prior exposure to complex aortic anatomy and pathology (3). However, ideal aortic surgeon trainees must have more than procedural skill; they must be able to develop judgment in patient selection, fluency in interpreting advanced imaging, and comfort working within multidisciplinary frameworks, often across prolonged and nontraditional training pathways. Given

existing structural limitations, we must consider how best to blend exposure across specialties in U.S.-based programs. The integrated vascular-to-thoracic pathway provides one model (1), but others exist. Joint programs, shared rotations, and collaborative curricula between vascular and cardiothoracic divisions can give trainees a stronger foundation in both open and endovascular techniques. Reducing barriers between specialties facilitates early-career practice, ensuring that graduates can maintain the breadth of skills they acquired during training.

Aortic repair is at a crossroads: As endovascular options expand, open case volumes decline; however, the complexity of contemporary open repair—that involving endograft explantation, infection, and complex reoperation—is on the rise. Open repair remains indispensable for many patients and is essential for training surgeons to manage complications or anatomy unsuitable for endovascular repair. Many trainees report receiving insufficient operative experience in complex aortic repair, namely open thoracoabdominal and aortic arch surgery; it is possible that flexible fellowships may be needed to provide highly-targeted training. Preserving this expertise may require concentrating open surgical training at high-volume centers and maintaining fellowship structures that guarantee hands-on exposure, longitudinal follow-up, and a dedicated aortic clinic. The standard of care for any such institution is to ensure dedicated clinical management to coordinate the complexities of lifelong adherence to imaging surveillance protocols; this includes serving as a primary care provider whenever possible.

Many graduates report difficulty finding positions that fully leverage dual training, particularly at academic centers where divisional boundaries persist. Such boundaries—wherein vascular surgeons and cardiothoracic surgeons separately “own” different segments of the aorta—can restrict graduates trained in both open and endovascular methods (4). We must ensure that early-career surgeons transition into practice environments that allow continued growth. This is where our institution’s mentorship and leadership should be protecting the development of new aortic trainees. Shared practice models within cardiovascular service lines may better reflect the real needs of aortic patients and support the development of versatile, hybrid-trained surgeons. At our own institution, we are actively shifting divisional boundaries. We have long been a center of open aortic surgery expertise, and we are now expanding our program to incorporate advanced endovascular capabilities, cadaveric training, and simulation

strategies as part of training. We will see firsthand how patients and trainees benefit from this emerging collaboration between our institutional divisions.

Conclusions

As the field of aortic surgery continues to evolve, the pathways that prepare future specialists must adapt with equal intention. Effective training requires thoughtful mentorship, graduated autonomy, and the ability to teach across specialties. The diverse training routes leading to fellowship, coupled with the limited number of high-quality, high-volume programs across the United States, highlight the need for structured, multidisciplinary development. Candidate criteria extend beyond technical skill to include curiosity, resilience, and a commitment to mastering both open and endovascular therapies. Despite ongoing obstacles—ranging from case-number limitations to misconceptions about the pathway—strengthening the pipeline through rigorous, balanced training will ensure that new aortic surgeons are not only technically proficient but also empowered to deliver exceptional care to patients with complex aortic disease. Creating sustainable pathways will require not only thoughtful trainee selection but also institutional willingness to design roles for practitioners that reflect how aortic disease is actually treated. It is critical that institutional leadership understand and support the evolving demands of training in complex aortic surgery, including the development of integrated, multidisciplinary programs that foster mentorship, preserve open surgical expertise, and enable the growth of hybrid skillsets.

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