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## Introduction: Evolution of vascular surgery training—Apprentice to fellow to integrated resident

This issue of *Seminars in Vascular Surgery* reviews the education and training of vascular surgeons in the United States and Canada. The aspiration to recognize vascular surgery as an independent specialty began with the 40 general and cardiovascular surgeons who founded the Society for Vascular Surgery after World War II, and their efforts to fulfill a professional need with the introduction of direct arterial surgery in clinical practice [1]. The first presidential address by Dr Alton Oscher on June 8, 1947 was entitled “Venous Thrombosis.” It took another 3 decades to establish accredited training programs in vascular surgery, and until 2006 to obtain a specialty (primary) Certificate in Vascular Surgery from the American Board of Surgery (ABS). During that time, there was an evolution in the education and training of vascular surgeons from an apprenticeship with a master surgeon(s), to an accredited fellowship after general surgery training, and now to 5-year integrated resident training programs leading to a vascular surgery certification alone. The articles in this issue review the current training paradigms from the perspective of the leadership of the Association of Program Directors in Vascular Surgery, Vascular Surgery Board of the ABS (VSB-ABS), Resident Review Committee in Surgery, and vascular surgery residents who are in training or recently completed a 0+5 integrated residency. The emergence of endovascular intervention for the treatment of vascular disease has radically changed vascular surgery from other surgical disciplines and introduced unique challenges in the education and clinical training required of future vascular surgeons. How to best train a vascular surgeon remains a work in progress.

The origins of vascular surgery training began in the 1960s, consisting of 1-year apprenticeships with surgeons who had established a vascular surgery service at their institution with a surgery resident rotation [1]. Although the SVS was founded in 1947 by pioneering cardiovascular and general surgeons of that era, the Society’s initial goal was to promote study and research in vascular disease and have an annual scientific meeting to better define the role of surgery in peripheral vascular disease [2]. The SVS bylaws endorsed the teaching of vascular disease care to medical students and residents and encouraged hospitals to develop special training for young surgeons interested in this emerging surgical specialty. In 1962, Malcolm Perry, MD, completed a 1-year vascular surgery

training program under the mentorship of Edwin J. Wylie, MD, at University of California—San Francisco, and is considered to be the first vascular surgery fellow. The number of “apprentice” vascular surgery fellowships grew in number throughout the 1960s and 1970s, spearheaded by the leadership of the SVS and the North American Chapter of the International Cardiovascular Society, which recognized the increased number (>70,000) of arterial operations being performed annually in the United States. In his 1969 presidential address to the SVS, C. Rollins Hanlon challenged his colleagues to strive for excellence by developing rigid standards and training programs in a new specialty of vascular surgery [3].

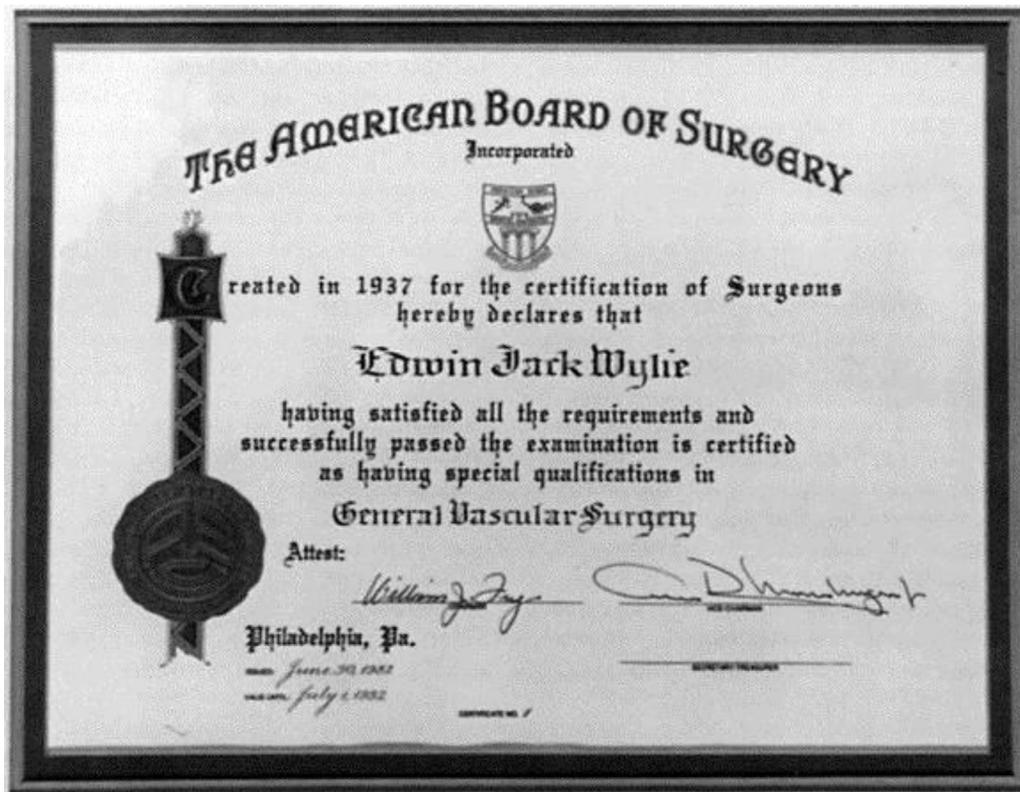
The effort to recognize vascular surgery as a separate surgical specialty was a topic of intense discussion throughout the 1970s and 1980s. General surgery residents completing training sought additional training in vascular surgery, especially those interested in an academic career. In 1974, the vascular societies sent a proposal to the ABS to establish a “Certification of Special Competence in Vascular Surgery” to recognize the unique education, training, and knowledge of this developing surgical specialty. The Vascular Committee of the Joint Council of Vascular Societies prepared guidelines for the essentials of programs in vascular surgery, but the ABS was not inclined to proceed with vascular surgery certification. In 1977, the Resident Review Committee in Surgery reviewed the professional societies’ recommendations for standards in peripheral vascular surgery training, and approved training could be obtained through the following three types of programs: (1) as a 12-month component of an accredited general surgery program in which the year of residency in vascular surgery is preceded by a minimum of 3 years of residency in general surgery and must be in addition to the minimum requirements for qualification by the ABS; (2) a vascular surgery residency combined with cardiothoracic training, the time requirement being in addition to the minimal requirements for qualification by the American Board of Thoracic Surgery; and (3) a 12-month free-standing supplemental program in vascular surgery after the completion of an accredited residency in general surgery or thoracic surgery. The resident should have a senior or chief resident responsibility in the operative management of a wide range of cases and in the range of one to two major operations per

week. In 1979, the Joint Vascular Surgery Council (SVS and North American Chapter of the International Cardiovascular Society) proceeded with accreditation of vascular surgery training programs using the “essential guidelines” developed years earlier. Seventeen programs were initially approved, and by 1982 there were 52 programs accredited by the vascular societies [4]. The era of vascular surgery fellowship training was a reality.

Vascular surgery is defined as the surgical specialty involved in the management of disease of the arterial, venous, and lymphatic circulatory systems, exclusive of those circulatory vessels intrinsic to the heart and intracranial vessels. As a vascular specialist in this discipline, the individual must not only demonstrate the knowledge, skills, and understanding of the medical science relative to vascular disease, but also technical skills and judgment regarding open or endovascular intervention. The resistance of competing surgical societies to recognize vascular surgeons as a unique group with special expertise in the treatment of vascular disease was overcome when, in 1982, Dr Wylie made a presentation to the American Board of Medical Specialists to approve certification of special competence. This led the ABS in 1982 to create a “Certificate of Special Qualifications in General Vascular Surgery,” which required successful completion of a written examination. Appropriately, the first certificate was issued to Dr Wylie, who had championed specialized training in vascular surgery for 2 decades (Fig. 1). Yearly written exams have been given since 1983 and oral examinations since 1986. In 1998, the VSB-ABS was founded, with its primary role being the certification of

graduates of Accreditation Council for Graduate Medical Education (ACGME)–approved vascular surgical training programs. In 2017, approximately 150 candidates took the written (qualifying) and oral (certifying) examinations, with failure rates of 2.5% and 13%, respectively. The VSB’s role in vascular surgery education is detailed in this issue by Ozaki et al, and includes certification and re-certification exam development and partnerships with other surgical training stakeholder organizations to ensure quality education and competence of the evolving vascular surgeon workforce. The next two articles by Drs Jordan and Eidt address the future of vascular surgery training and the continued aspiration of an independent surgical specialty recognized by the American Board of Medical Specialists. These leaders in vascular surgery recognize that the education of future vascular surgeons requires an evolving paradigm with training milestones, new hands-on endovascular skills, and certification of competence by a Vascular Surgery Board independent of the ABS and general surgery.

Vascular surgery training paradigms are similar in the United States and Canada, with both countries providing a pathway directly after medical school. The article authored by Duncan and Power details resident training in the 10 Canadian programs. Similar to training in the United States, the recent emphasis has been on shortening resident training from 7 to 5 years, but Canadian programs are more flexible in the senior year, allowing rotations away from their home institution, which can assist in their job search. Prolonged 5-year or longer training in general surgery before entry into the 5+2 vascular

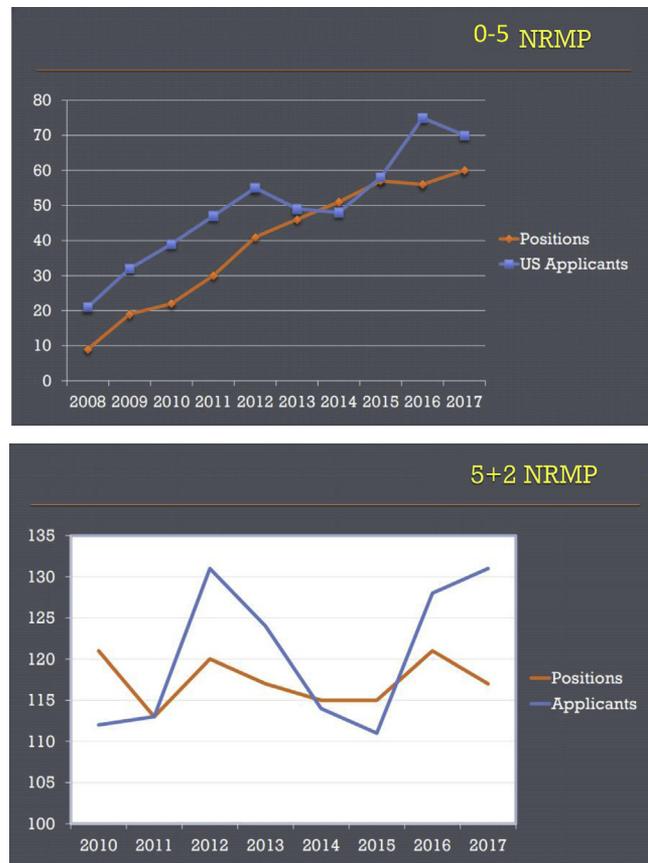


**Fig. 1 – Photograph of the first American Board of Surgery Certificate in General Vascular Surgery, awarded to Edwin Jack Wylie, a leader in recognizing vascular surgery as a separate specialty, on June 30, 1982.**

surgery training program is cited by medical students as a reason not to pursue a career in vascular surgery. Similar to the US ACGME Milestone system, the Canadian Royal College of Physicians and Surgeons is converting to a competency-based curriculum that focuses more on trainee outcomes and learning than on time. The Canadian Competence by Design program, a 2-year curriculum, is required for multiple medical specialties and includes the following categories: medical expert, which includes the ability to perform patient-centered clinical assessment and establish a management plan, plan and performance of procedures and therapies, establishing plans for ongoing care, involvement in care team; communicator, which includes establishing therapeutic relationship with patients and families; collaborator; leader; health advocate; scholar; and professional. Trainees must pass their Royal College written and oral exams before completing residency, which imparts stress in the second half of the final year of training for exam preparation, but ensures the graduate is Royal College–certified when he/she is done.

In the United States, ACGME accreditation of training programs is based on the concept of graded and progressive responsibility under supervision in a setting of a graduate medical education program that provides safe and effective patient care, and is organized to assure that each resident/fellow acquires the knowledge, skill, and professional ethics to enter the unsupervised practice of vascular surgery [5]. As of 2019, there are approximately 550 trainees in 109 traditional 5+2 fellowships and 60 integrated 0+5 resident ACGME-approved vascular surgery training programs. The 0-5 integrated residency pathway has seen the greatest growth in new programs, beginning with 9 programs in 2008; while the number of positions in the 5+2 pathway has remained steady, with approximately 120 positions available each year. The integrated residency must be at least 60 months in duration, and in both training pathways the trainees must perform more than 250 major vascular reconstructive procedures. A major obstacle for establishing a new 0-5 training program has been the difficulty in obtaining institution funding for additional resident positions. Interest in vascular surgery training remains high, with more applicants than positions for both pathways (Fig. 2). Successful recruitment of medical students and surgery residents to a vascular surgery career requires that programs recognize their desire for hands-on mentoring and aspirations for new endovascular methods for vascular patient care, while ensuring an appropriate work–life balance.

In the next three articles of this issue, vascular surgery residents provide their perspective regarding the 0-5 resident training paradigm as being adequate preparation for community practice (Wooster), the challenges of maintaining personal well-being during training (Audu and Coleman), and case load comparison of graduates from 5+2 fellowships and the 0+5 integrated residency (Tanious). A thoughtful read of these articles reveals that vascular surgery training is rigorous and requires a committed faculty and supportive institution. Limitations of work hours and the ACGME requirements for scholarly activity and a quality assurance project during training mandate a well-organized education curriculum. Burnout is a real possibility for the trainee, and highlights the need for some flexibility in rotation schedule and time for



**Fig. 2 – Graphs showing the number of applicants and positions in the annual National Resident Match Program (NRMP) for the 0+5 and 5+2 vascular surgery training programs from 2008 to 2017.**

research. A case load comparison of the traditional 5+2 year and the integrated 0-5 year training programs has confirmed differences in trainee experience, most noted in open abdominal aorta procedure experience, which is high in the 5+2 fellows due to their prior general surgery training. The integrated vascular surgery trainee has the advantage of increased time spent on vascular services, which results in significantly increased major vascular case volume and vascular laboratory experience. The integrated residency programs have increased the number of women in vascular surgery and the graduating 0+5 integrated resident is more inclined to pursue an academic career [6].

The advent of endovascular therapies for arterial and venous disease has resulted in dramatic restructuring of vascular surgery training programs, many with specific endovascular surgery rotations with trainees performing procedures in a hybrid operating room and/or interventional radiology suite. The article from the Stanford vascular surgery group highlights the role of industry in fellow/resident education. The authors correctly indicate that compared to other surgical specialties, trainees must become competent in both open and image-guided endovascular interventions to become contemporary vascular surgeons and compete with interventional cardiology and radiology in vascular patient

care. The rapid growth of endovascular technology and device innovations requires industry partnerships that enhance hands-on learning by providing the products, training seminars, research support, and travel assistance. Newer endovascular devices being applied routinely for patient care in Europe and Canada are not US Food and Drug Administration–approved for patient use. The ability of trainees to develop a relationship with industry allows one-on-one exposure to developing technology that will be applied in the future, and helps establish the concept of life-long learning.

In the last three articles of this issue, the focus is on the development of hands-on skills in nonvascular vascular testing and the role of simulation-based training. The article by Eiberg et al from Denmark emphasizes that physicians who are experienced in duplex ultrasound testing can better serve their patients and be able to assist vascular surgery trainees who need to acquire this clinical skill. In my article (Bandyk) on education and hands-on training in vascular laboratory testing, I outline the requirements of the vascular laboratory curriculum and the education milestones based on the year of training. Curriculum essentials include an accredited vascular laboratory, technologist and physician mentors, and a duplex scan in the operating room and vascular clinic. I routinely perform duplex testing in my vascular clinic during patient evaluation, which allows the residents to make point-of-care decisions based on their hands-on ultrasound assessment. In contrast to Europe, the ACGME vascular surgery trainees must pass a vascular laboratory interpretation test in order to apply for ABS certification. In the last article, Erfan et al engage in a discussion of the role of simulation-based training to refine technical endovascular skills. The authors are members of the Association of Program Directors in Vascular Surgery Education Committee, which is tasked with developing a testing module that evaluates the fundamentals of vascular and endovascular surgery. The pros and cons of the various simulation models and their roles in trainee education and skill demonstration are detailed. It is possible that in the future, simulation will be used to evaluate and test the fundamental endovascular skills of trainees. At present, the VSB-ABS does not accept simulation experience as a proxy for patient case logs. The authors opine that the number of cases is an indirect measure of technical skill and procedural competence, and they propose that training program educational milestones include the use of objective tools, for example, simulations, to demonstrate technical competence.

The future of vascular surgery is dependent on recruiting a new generation of talented men and women into this specialty known for its challenging technical procedures and complex decision making. Vascular surgery has been blessed with the leadership of the SVS and Association of Program

Directors in Vascular Surgery, which is committed to training the best vascular surgeons in the world. There is no doubt that the ACGME accreditation of vascular surgery training programs and ABS-VSB certification of vascular surgeon competence has improved the quality of patient care. The American public can be confident that a board-certified vascular surgeon is truly a vascular disease specialist with expertise in both open and endovascular interventions. In the clinical areas of aortic aneurysm and critical lower limb ischemia, vascular surgeons have been the innovators and leaders in treating these life- and limb-threatening conditions. The evolution of vascular surgery is embodied in the generations of surgeons who began performing open arterial reconstructions, research the role of surgery in the treatment of vascular disease, and aspired to make it a separate specialty. It is clear that 0+5 integrated residency is the future of vascular surgery training, but its continued development requires an independent Resident Review Committee and VSB that ensure practicing community and academic vascular surgeons are making the decisions vital to this evolving surgical specialty.

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<https://doi.org/10.1053/j.semvascsurg.2019.05.005>  
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