Curr Surg Rep (2019) 7:16
https://doi.org/10.1007/s40137-019-0236-y

Vascular Acute Care Surgery (VACS) Services: A New Model for the Future and a Solution to the Emerging Vascular Surgery Coverage Crisis

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Published online: 16 May 2019

Abstract
Purpose of Review The following is a comprehensive review of the current practice of Vascular Surgery, highlighting the existing gaps in vascular surgical care and delivery and providing evidence-based suggestions for improvements moving forward.
Recent Findings Recent data demonstrate that a shift of many vascular surgical procedures from extensive, high-risk, inpatient operations toward minimally invasive, endovascular, same-day surgeries has created a gap in the ability of the community-based vascular surgeon to adequately care for acute vascular events.
Summary The trends towards outpatient vascular surgery, coupled with the increasing demands of acute vascular surgical expertise for less-common open and high-risk procedures have created a crisis in the field. When the field of General Surgery was at a similar crossroads in the early 2000s, the community responded with the development of Acute Care Surgery (ACS) services to manage resource-intensive emergencies. Vascular surgery should learn from the ACS experience and consider the development of Vascular Acute Care Surgery (VACS) services responsible for the care of acute vascular patients.

Keywords Vascular surgery · Acute care surgery · Vascular acute care surgery

This article is part of the Topical collection on *Vascular Surgery*.

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Introduction

Over the course of the last 25 years, the field of Vascular Surgery has undergone a significant change in its patterns of care, shifting towards endovascular procedures and increasingly into the outpatient setting. These trends represent a significant departure from the field's origins in extensive, open procedures.

Up until the mid-twentieth century, Vascular Surgery was primarily an acute care specialty [1]. In 1964, the three most common vascular procedures were amputation, sympathectomy, and management of traumatic injuries [2]. Over time, with advances in surgical technique and patient safety, Vascular Surgery was able to incorporate more elective procedures. By 1989, carotid endarterectomies, open abdominal aortic aneurysm repairs, and lower extremity bypasses were the most common procedures [2]. In the last quarter century, technological advances in diagnostic and therapeutic modalities have allowed vascular surgeons to expand their practice to comprehensive care of the vascular patient, which includes diagnosis and medical management [3].

Since the early 2000s, there has been a sizable increase in the volume of endovascular surgery (Fig. 1) [4, 5]. Given the decreased complications and length of stay associated with endovascular surgeries, it is not surprising that Vascular Surgery has trended towards an outpatient model [6]. Underscoring this evolution is the increase in outpatient percutaneous endovascular aortic aneurysm repairs (EVAR)—a complete transformation from the traditional, inpatient based, open abdominal aortic aneurysm (AAA) repairs of the past [6]. Similarly, advances in peripheral arterial and venous disease treatments have led to an ever-increasing number of vascular surgeons moving towards a predominantly office-based procedure practice (Fig. 2). Jones et al. examined Medicare data and found that outpatient peripheral vascular interventions increased 31%, and in-office interventions skyrocketed by more than 600%, while inpatient procedures fell 23% between 2006 and 2011 [7]. The result of these trends is that vascular surgeons are spending more time in their office and in ambulatory surgery centers and less time in Hospital-based settings.

Despite these shifts in practice, vascular surgeons are still responsible for providing care for acute vascular patients arriving in Emergency Departments nationwide. The volume of patients presenting with acute vascular problems has never been higher. One review of the National Trauma Data Bank revealed a significant need for vascular surgery expertise for severely injured patients. They found that a vascular surgery procedure was performed on 7% of patients in the database compared to emergent general surgery procedures in 12% of patients [8]. Outside of trauma, analysis from the Health Service Cost Review Commission data from Maryland detailed that out of 154,000 inpatient admissions for vascular interventions over three years, two-thirds were admitted acutely [9••]. These admissions included acute limb ischemia, ruptured and dissecting aneurysms, graft infections, and

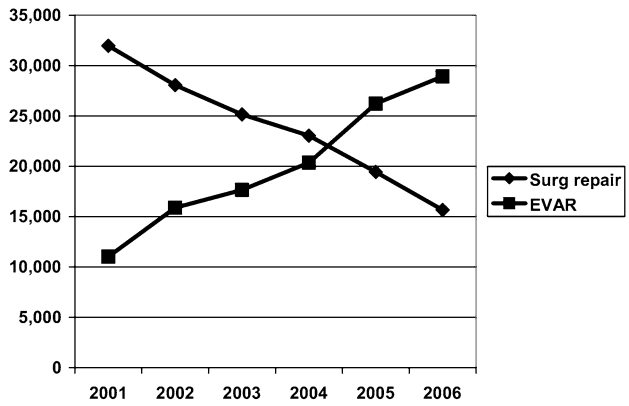

Fig. 1 Reprinted from Levin et al. (2009) with permission from Elsevier

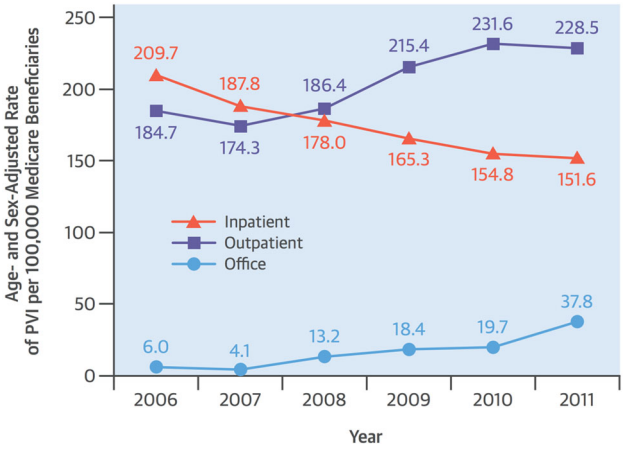

Fig. 2 Reprinted from Jones et al. (2015) with permission from Elsevier

acute deep venous thromboses. These data suggest that as vascular surgery moves towards an outpatient model, an increasing proportion of inpatient vascular surgery patients are urgent or emergent. Similar data have been reported in the UK, where the number of emergent vascular referrals rose 50% from 1990 to 2003 [10]. These data demonstrate that many patients are continuing to be admitted for acute vascular problems, while vascular surgeons move towards the previously described outpatient model. The question of who will care for the acute vascular surgery patient becomes more pressing. The same influences that were present in general surgery when Acute Care Surgery (ACS) developed into its own specialty are now seen in vascular surgery: a lack of emergency room coverage, transition of procedures into the outpatient setting, advancement in minimally invasive techniques, and a lack of specialist training in complex acute care procedures. In 2018, we believe that the proactive incorporation of a Vascular Acute Care Surgery (VACS) service in tertiary referral centers will meet the needs of this shift in practice pattern and the increasing aging population.

Impediments of Contemporary Vascular Surgery Practice

A recent survey published in Journal of Vascular Surgery described the state of practice of modern vascular surgeons. The majority of vascular surgeons reported working > 60 h per week, 70% of which stated that their compensation was directly tied to productivity [5]. In short, vascular surgeon's time is scarce, and their compensation is linked to the way they use their time. The economics of Work Relative Value Unit (wRVU) production-based compensation support maximizing elective schedules. A vascular surgeon might produce 69 wRVUs ($2470

Medicare dollars) by scheduling two EVARs in the IR suite in the morning and four great saphenous vein ablations in his/her office that afternoon. Meanwhile, spending the entire day caring for a ruptured AAA in the ED and operating room may only generate 51 wRVUs ($1826 Medicare dollars) [11, 12]. This comparison does not take into account the time that will be required for that surgeon to actively participate in the care of a patient who will likely end-up in the ICU for several days and potentially requires additional trips to the operating room. When adding this time (i.e., time to round, interact with families, and provide all the post op care of such a case), the comparison is even more unbalanced. This dynamic contributes to the current trend towards increasing elective and outpatient practices in order to satisfy the economics of balancing a modern Vascular Surgery practice.

The shift in Vascular Surgery away from extensive, open operations has also been met with a change in the training focus. During their training, Vascular Surgery residents and fellows are more commonly performing endovascular and outpatient surgery in lieu of treating vascular emergencies. The decrease in open case volume for residents has been extensively documented [8, 13, 14]. Meanwhile, a linear relationship between increasing surgeon case volume and decreasing mortality has been described in open AAA repairs (Fig. 3). Surveys have suggested that graduating chief residents may lack confidence in their ability to perform open abdominal vascular cases and vascular trauma cases [15, 16]. An additional factor limiting exposure to emergency cases is the 80-h work-week. Studies suggest that the total volume of cases for trainees, including acute vascular cases, has decreased [17]. Vascular surgery trainees are impacted by these trends [18]. The rise of endovascular options for aortic disease has resulted in a decrease in vascular fellow experience with open abdominal repair. Sachs et al. reported that vascular surgery fellows open abdominal case exposure was cut in half between 1995 and 2008 [19]. That trend continues today. As a result, concerns have been raised that in the coming years, graduating vascular fellows may not be adequately prepared to care for higher acuity emergent vascular patients requiring open operation [20].

Along with the current changes in the vascular field, the lack of recognition of the importance of and adequate care of acute vascular disease in our present practice also needs to be revisited [21]. This oversight is especially demonstrated when comparing the treatment of and protocols for ST segment elevation myocardial infarctions (STEMIs) compared to those of acute limb ischemia (ALI). STEMIs are associated with significant morbidity and mortality, require emergency and time-critical treatment for successful outcomes, and incur substantial inpatient costs [22–24]. Evidence from numerous randomized control

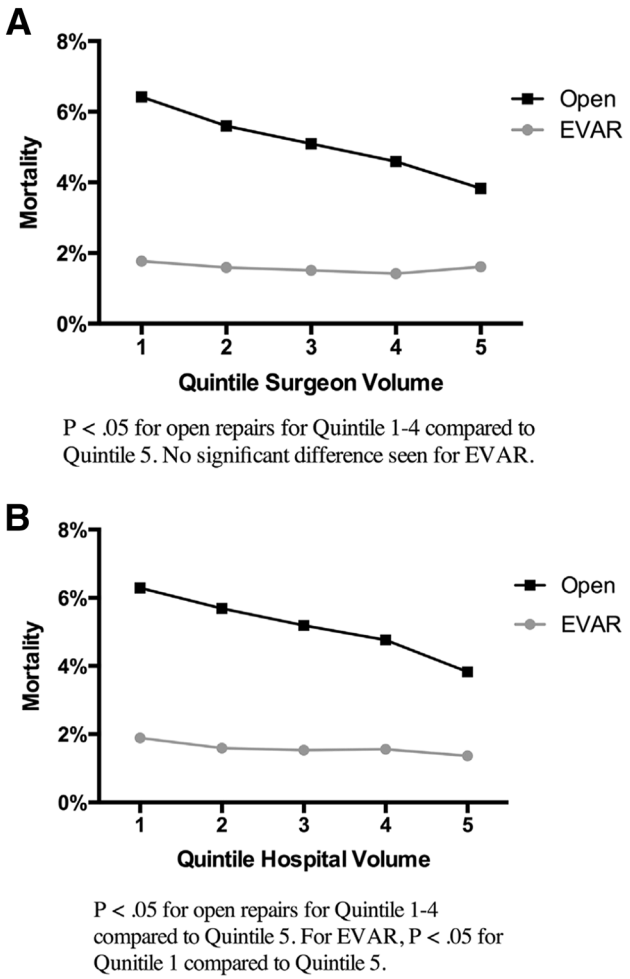

Fig. 3 Mortality rates for open repair and endovascular aneurysm repair (EVAR) by **a** surgeon volume and **b** hospital volume. Reprinted from Zettervall et al. [60] with permission from Elsevier

trials demonstrated that percutaneous coronary intervention (PCI) is the best treatment for STEMI, but the timely and adequate delivery of PCI can be challenging [24]. To address this, specialized regional centers and systems with required credentialing were developed to streamline care for STEMIs and have since demonstrated a positive influence on outcomes [25, 26]. As a parallel, acute limb ischemia is also associated with significant morbidity and mortality, requires emergent time-critical treatment for successful outcomes, and incurs substantial inpatient costs [21, 23, 27]. Evidence has also established appropriate treatment protocols for ALI (Fig. 4) [28]. Yet, despite the clear overlap of these two cardio-vascular emergencies, there remains a deficit in the delivery and quality of appropriate ALI care [29]. It is therefore necessary to consider how a network of specialized regional centers and systems could be implemented to address vascular emergences, like ALI, as was done for STEMIs. The current

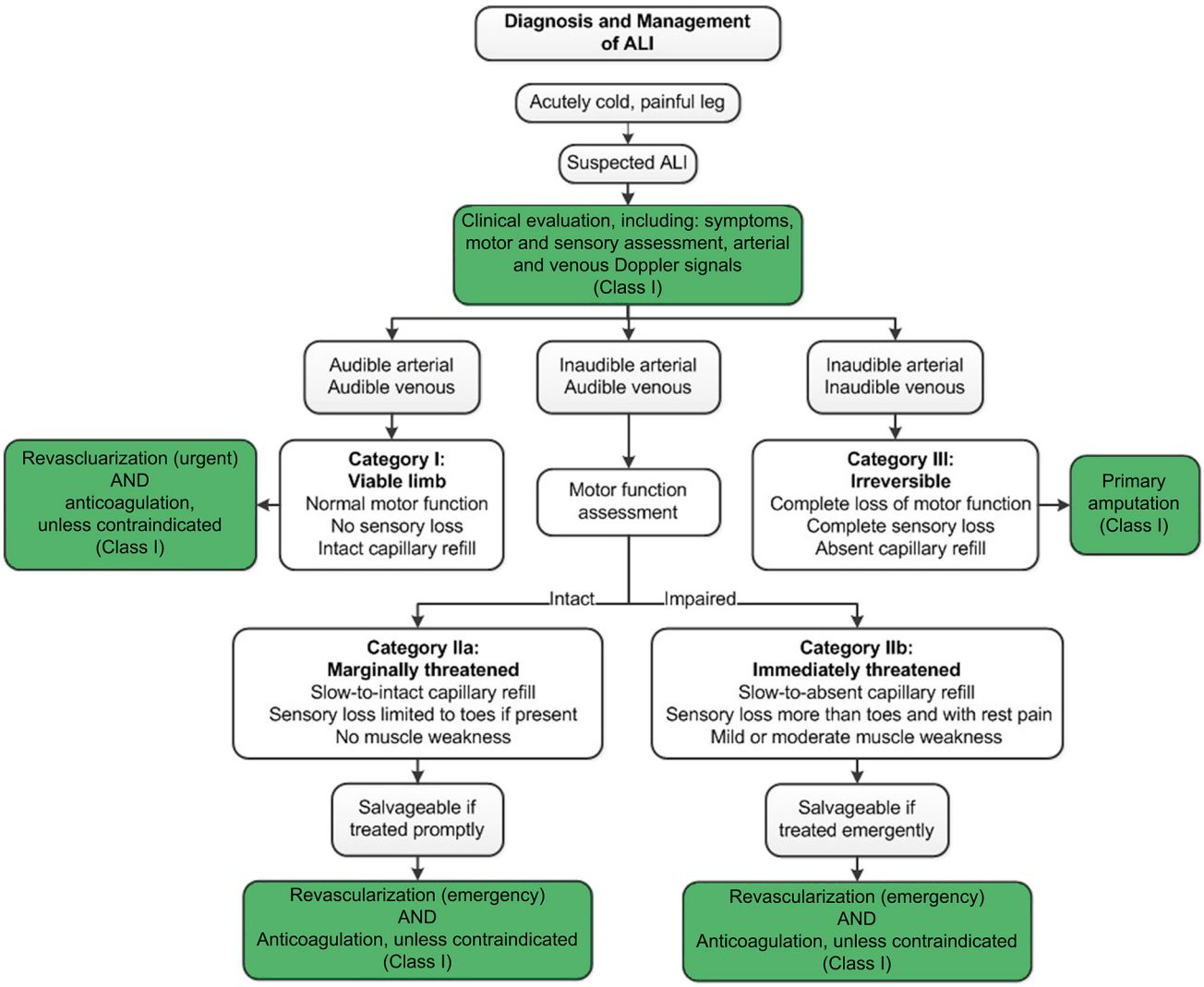

Fig. 4 2016 AHA/ACC guideline for diagnosis and management of acute limb ischemia. Reprinted from Gerhard-Herman et al. (2017) with permission from Elsevier

state of vascular surgery makes this type of triage system difficult.

Wang et al. described challenges with patients referred for ALI. At outside hospitals, patients had an average delay from symptom onset to evaluation of > 18 h and the majority of patients (58%) arrived with sub-therapeutic anticoagulation [30]. This underscores the need for innovation in the delivery of VACS now and in the future. The same argument can be extended for other vascular emergencies, such as aortic problems, for which no standardized protocols or credentialing requirements by accepting institutions exist to guide transfer and treatment.

To make matters more pressing, population trends suggest that the demand for vascular specialists will soon outstrip the supply. Williams et al. describe the linear growth in the number of vascular surgeons being overwhelmed by the exponential growth in patients with vascular disease by 2030 [31]. As a result of these factors, the ability of vascular surgeons to adequately care for these patients has been reasonably called into question [32•, 33]. Dr. Tej Singh, in his editorial *Present Vascular Surgery Challenges are Magnified in Our Emergency Rooms*, wrote "the biggest void in our specialty may be coverage to our emergency rooms…Emergency rooms nationally are at risk of not having appropriate, experienced vascular coverage." A letter response to this editorial, also in the vascular Specialist, added:

> How can a busy private practitioner with a full daily schedule, suddenly drop it completely in order to take care of an emergent ischemic limb that might take him/her most of the day? How comfortable or excited

is a practitioner to take on a juxtarenal aneurysm, of which he/she may see and operate on one or two times a year?

The Experience of General Surgery as a Model for Vascular Surgery today

In the early 2000s, the field of General Surgery was at a similar crossroads. The volume of patients presenting with acute surgical needs was on the rise, yet the number of surgeons trained and willing to care for them was declining [34]. The number of practicing general surgeons fell more than 25% from 1981 to 2005 [35]. This coincided with the rise of laparoscopic procedures, an effect that has been mirrored in vascular surgery with the advent of endovascular surgery. Additionally, there was an increasing trend away from General Surgery into specialist-driven, fellowship-based practice. Trauma surgeons were increasingly treating their own patients non-operatively, while losing general surgery cases to organ-specific practices [34]. Nearly four out of every five graduating residents were pursuing specialized fellowship training [36]. The need for quality acute General Surgery care was never higher, yet trainees were seeking career opportunities outside of traditional General Surgery.

Laparoscopic procedures significantly reduced the postoperative morbidity and mortality associated with surgery. As a result of the decreased hospital stays and quicker recovery times, laparoscopic surgeries moved towards an ambulatory model [37]. Ambulatory surgery centers expanded in many markets and the number of outpatient procedures rose. Data from the 2002 Medical Online Survey Certification and Reporting System, along with the American Hospital Association Annual Surveys of Hospitals from 1993 to 2001 showed a 28% increase in outpatient surgeries and a 4.5% decline in inpatient surgeries [38]. The late 1990s to early 2000s saw the demand for acute general surgical care rise while the supply of surgeons willing to cover acute general surgery emergencies dwindled. These converging forces led to Emergency Departments nationwide reporting difficulties with obtaining General Surgery coverage [39].

Within the next decade, the surgery community responded to this crisis with the development of Acute Care Surgery (ACS) services in 2005 [34]. The ACS model led to a major paradigm shift in general surgery practices nationwide (Fig. 5). By establishing ACS services, institutions dedicated specialists to covering the needs of their emergency rooms and freed most of their general surgeons to perform elective general surgery without the interruption of emergency cases. Surgeons could schedule full operating room days without worrying about the critical patient arriving in the emergency department and disrupting an already busy schedule.

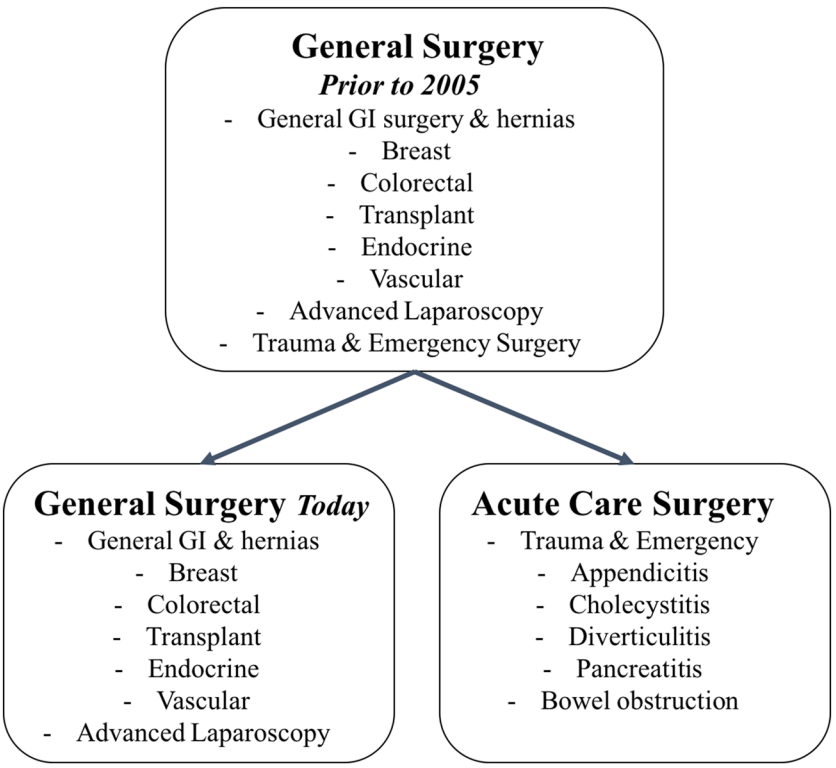

Fig. 5 The division of general surgery and acute care surgery

The actual makeup of ACS programs varies nationally and across the globe [40]. Generally speaking, these programs are centered on the need for complex, non-elective care. Larger bed, urban, academic centers are more likely to have adopted ACS services. Nearly half of all university teaching hospital centers have some type of ACS model. As independent hospitals increasingly become part of larger academic or private hospital networks, these centers often act as referral hubs for the sickest patients within their network and in their immediate community [41].

At the same time, the shift increased economic productivity for both elective and non-elective surgery. Miller et al. found that hospital collections increased 39% in the post-ACS period, with gains in both the acute care group and elective patient groups at their institution [42]. After the implementation of an ACS service, Michailidou et al. described significant improvements in wait time for surgery, a reduction in length of stay (LOS) by 1.2 days, and a cost savings of $1000 per patient for patients undergoing gallbladder surgery [43]. Likewise, Austin et al. demonstrated increased elective general surgery volume as well as improved utilization of ICU and operating room resources after departmental restructuring to include an acute care surgery service [44]. It is thus clear that the ACS model provided and continues to provide an undeniable enhancement in economical productivity. The same could be true with the creation of a Vascular Acute Care Surgery model.

Beyond the economic advantages of the ACS model, significant improvements in patient outcomes were appreciated. In appendicitis, ACS led to lower rupture rates and decreased LOS [45]. Cubas et al. noted improved LOS in both cholecystitis and appendicitis patients, as well as decreased complications in the cholecystitis group after implementing ACS-based practice [46]. More recent meta-analyses have confirmed these findings for both disease processes [47].

In summary, the field of General Surgery solved their crisis of inadequate emergency general surgery services by spinning off a new specialty—Acute Care Surgery, which is focused specifically on addressing the needs of emergency general surgery patient populations while at the same time producing considerable financial and outcomes success as a result of this change.

Vascular Acute Care Surgery (VACS): The Way Forward

Vascular Surgery, as a field, can learn from the ACS experience. Similar to the partition of Acute Care Surgery from General Surgery, a Vascular Acute Care Surgery (VACS) program could be developed to care for patients with acute vascular problems, while leaving the elective work to office- and outpatient-focused vascular surgeons (Fig. 6). The scope of practice of a VACS program could

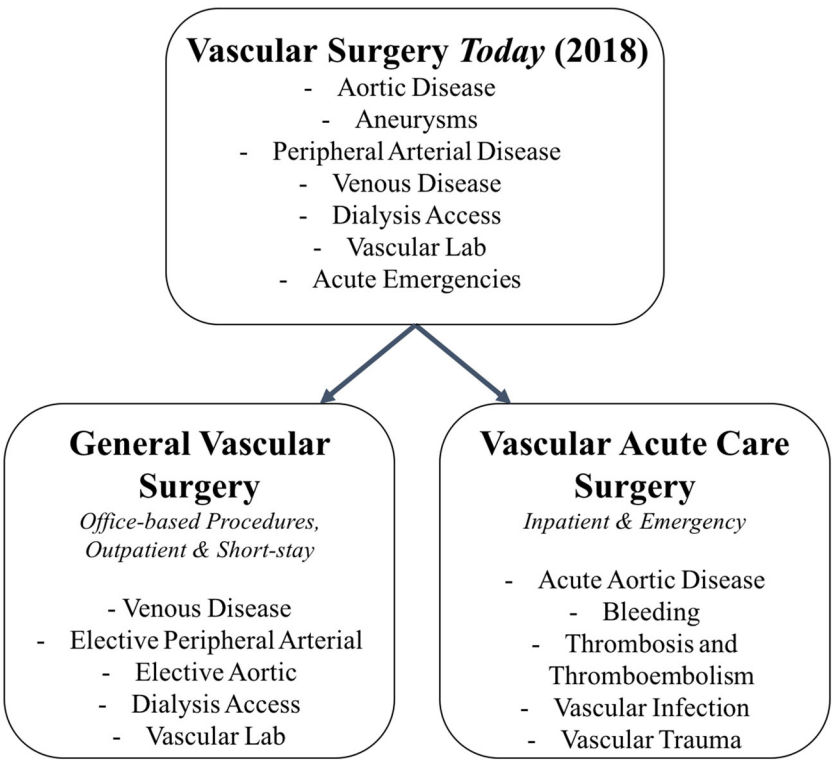

Fig. 6 The potential division of vascular surgery and vascular acute care surgery

include aortic syndromes, acute limb ischemia, acute mesenteric ischemia, vascular infections, and vascular trauma if institutionally relevant (Fig. 7).

The VACS service would provide specialized care to these acute vascular patients and free their vascular surgery colleagues for more predictable and productive operating room schedules. As was the case with the ACS model, creating such a program within a clinical structure dedicated to acute vascular care will likely improve patient outcomes, clinical processes, productivity and decrease costs. Given the large resources needed to sustain them, it remains to be seen if dedicated Vascular Acute Care Surgery services will be concentrated exclusively in academic centers or large group practices; nonetheless, we believe this model could play an important role in the future of modern vascular care.

Proof of Concept

Ruptured Abdominal Aortic Aneurysm Protocol at Albany Medical College

In 2002, The Vascular Group at Albany Medical College developed a multidisciplinary protocol for endovascular treatment of ruptured AAA. By integrating vascular surgeons, ED physicians, anesthesiologists, and support staff into a cohesive team, with standardized instructions for diagnostic and therapeutic approaches to ruptured aortic aneurysms, the team was able to demonstrate a mortality rate of 18%, significantly lower than the 35–80% reported previously [48]. Their protocol focused on a standardized approach with the vascular surgeon as team leader (Fig. 8) [49]. This disease specific protocol can be viewed as a model for how a Vascular Acute Care Surgery program could function. Such a program could employ similar standardization of treatment protocols, improved regionalization, and dedicated resources for a range of acute vascular problems.

Vascular Surgery Hospitalist at University of South Carolina-Greenville

Impressed by the successes of the Acute Care Surgery model, a group at Greenville Memorial Hospital, part of the University of South Carolina system, instituted a Vascular Surgery Hospitalist (VSH) program in 2003 [50]. Although not specifically designed to handle only vascular emergencies, there are many parallels between this model and the ACS model. The VSH system includes a doctor of the week, who covers inpatients, consults, vascular labs, and the emergency department. This vascular surgeon also covers any urgent or emergent cases that arise. As a result of these changes, they found their average daily census fell from 32 to 21 patients, their average length of stay dropped nearly 2 days and the percentage of surgeries taking place

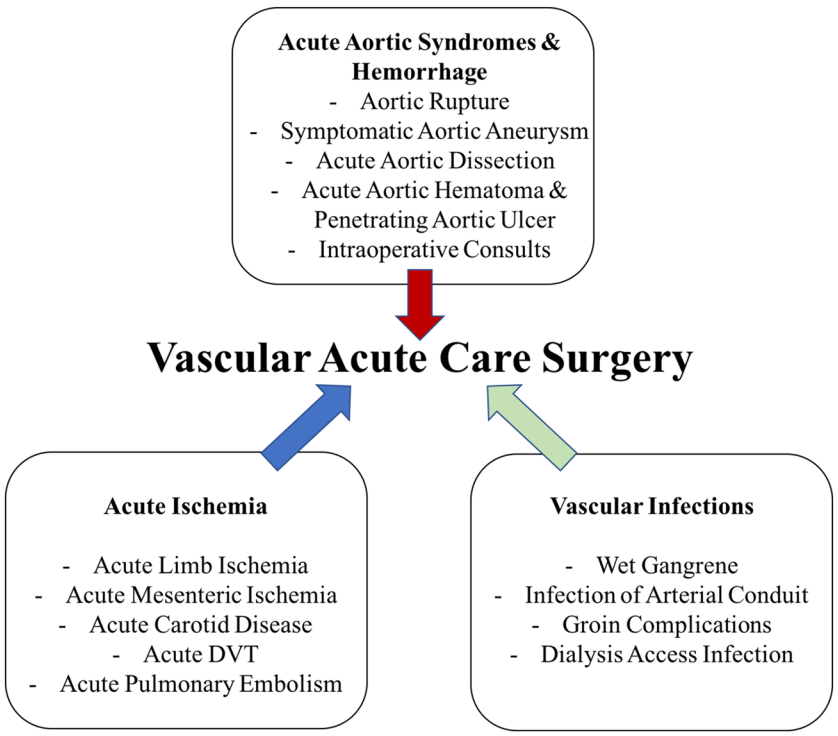

Fig. 7 The scope of practice of a vascular acute care surgery service

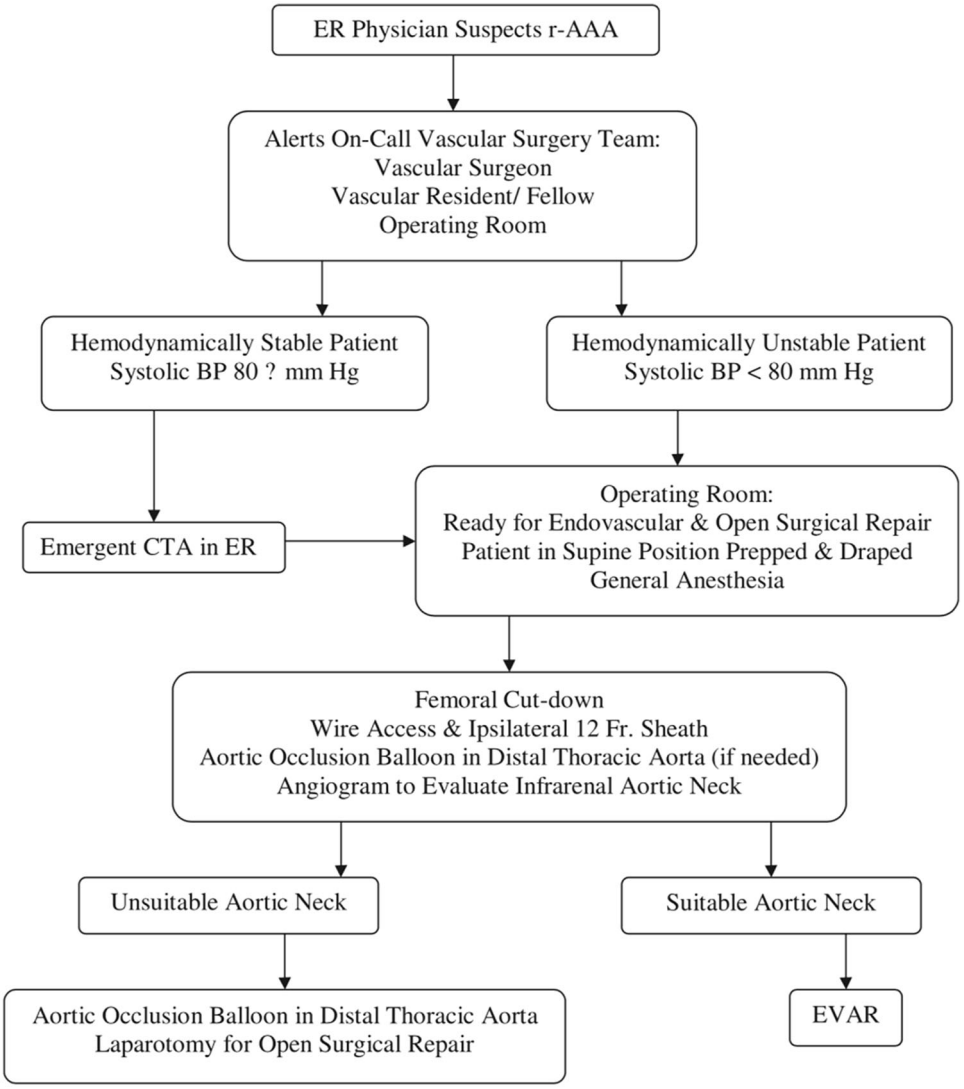

Fig. 8 The Albany Vascular Group Approach to r-AAA. Reprinted from Mehta et al. (2006) with permission from Elsevier

after hours were halved [50]. Their results echo the data published in the ACS literature—patient and hospital outcomes were improved by dedicating a surgeon to the care of urgent and emergent patients.

Vascular Acute Care Surgery at the University of Maryland

A group at the University of Maryland began studying and conceptualizing a Vascular Acute Care Surgery program in 2017. Harris et al. reviewed a state-wide database of inpatient hospitalizations for urgent and emergent vascular surgery patients to characterize the burden of acute vascular disease [9••]. They found that 67% of patients admitted in Maryland for vascular surgery had received acute care. These patients required more critical care resources such as transfusion, dialysis, and mechanical ventilation. Acute patients had significantly higher length of stay, charges, and mortality than elective vascular patients. Their findings suggest that the potential scope of VACS is very large and includes the most severely ill vascular patients.

In a second study, the group analyzed the Maryland Health Services Cost Review Commission database to better understand how regionalization of vascular acute care surgery patients could potentially benefit patient outcomes [51]. They found that acute vascular patients transferred to referral centers were 50% more likely to die than patients directly admitted to those centers. They also discovered significant differences in use of critical care resources, hospital LOS, and charges. Multivariate analysis revealed that transfer status was an independent predictor of mortality for VACS patients. Their results provide data to confirm the

concerns voiced by Singh and Campbell that on-call emergency vascular coverage is inadequate [32•, 33]. In their study, the inability of primary hospitals to care for their VACS patients caused critical delays leading to worse outcomes in this population.

Together, these studies support the need for improved VACS services. Due to the sheer volume of VACS patients and their extensive resource use, VACS patients are a major burden to hospital systems. The bottom line is that, VACS patients who arrive at hospitals unprepared to handle their complex problems and require transfer to regional centers have considerably increased morbidity and mortality. While many vascular interventions may not require dedicated acute care services, there is a definitely a subgroup of patients—across medical and surgical specialties alike—with high illness severity who require complex, resource-intensive surgical and perioperative care who would likely benefit from an acute vascular model. Services such as specialized anesthesia care, blood bank resources, advanced nursing care, perfusionist support, and advanced, real-time hematologic analysis (thromboelastography/ROTEM) are simply not available in referring facilities but may offer significant benefits to this subset of patients.

Manzur and Leithead explored the impact of vascular consults in the hospital setting in a pair of studies with findings that echo this sentiment. Manzur et al. demonstrated that the need for vascular consults in the hospital is frequent, usually unplanned, and when requested, often necessary for the completion of a surgical procedure [52•]. Leithead et al. found that approximately 58% of after-hour vascular surgical consults resulted in urgent patient care (surgical intervention within 24 h) [53]. It is thus clear that a VACS model would not only serve as a valuable tool for the triage of vascular patients, but also as an invaluable resource for ensuring the delivery of appropriate and timely inpatient care.

Furthermore, in data not yet published, the Maryland group examined the effects of multidisciplinary rounds and clinical pathways to discharge on patients admitted to their service. They found that integration of MDR, early discharge planning for complex conditions, and implementation of VACS service model led to a 2.8-day reduction in LOS and a reduction in 30-day readmissions. [Aicher et al. Unpublished Data, 2017] The Maryland model suggests that a multidisciplinary service integrating VACS specialists, vascular fellows, advanced practice providers, nurses, and allied health professionals dedicated to care of the VACS patient can significantly improve outcomes for patients and hospital systems alike.

Level One Vascular Emergency Program at Cooper University

In 2017, the vascular surgery group at Cooper University Hospital in Camden, NJ, developed and implemented a "Level One Vascular Emergency" (L1VE) program. This program was specifically designed to expedite transfer for urgent and emergent vascular pathologies. The L1VE program has a 24/7 hotline, where potential referring providers can be connected to a nurse for triage and easier physician–physician communication. They additionally describe activation of vascular specific resources and a new system for easier transfers of imaging. McMackin et al. published the early results of their new program and noted a 32% increase in Acute Aortic Syndrome transfers, amid a 13% overall increase in transfer case rate for acute vascular surgery patients after implementing the L1VE program [54]. Their program is strong evidence for the feasibility of more advanced regionalization and specialization of acute vascular surgery pathologies.

These early attempts to develop programs to improve the care of acute vascular patients demonstrate that regionalization, specialization and dedication of resources can improve outcomes. When viewed in concert with the data from the ACS experience, the potential of a VACS model is at the very least promising. If implemented, and if the ACS experience is an indicator of the future for vascular care, Hospitals could expect to increase productivity from both their elective and non-elective vascular surgery caseloads.

Future Directions/Proposed Elements

For Vascular Acute Care Surgery programs to be successful, lessons learned from the creation of the Acute Care Surgery model must be incorporated. Although individual ACS programs structure and exact protocols vary from institution to institution, certain core elements are maintained across centers [42]. Each center must identify specific disease processes for which they wish to transfer coverage to their acute service. A possible spectrum of acute vascular pathologies is described in Fig. 7. We believe the Acute Care Vascular Surgery service could cover acute aortic syndromes, acute limb and other ischemia, vascular infections, thromboembolic pathologies, and vascular trauma where applicable.

To best provide care for these disease processes, the entire spectrum of care for VACS patients would need to incorporate ordered, protocolized care to ensure good

outcomes. Rapid transfer hotlines and systems would need to be formalized or updated as seen at Cooper and Maryland. Disease specific perioperative management protocols like the Albany AAA protocol would need to be developed and implemented. Associated post-operative care pathways, as seen in the Maryland VACS model, would likewise need to be formalized to ensure survival benefits and appropriate resource utilization.

Transfer of coverage for certain disease processes will likely be economically and politically challenging and for this reason individualized spectrums of care will be necessary across institutions. ACS centers across the nation employ a wide spectrum of physician coverage models [55]. Given that the volume of acute vascular patients may be somewhat lower than the ACS patient lists, a surgeon of the week model will likely be the ideal configuration for a VACS service. This system would allow other vascular surgeons to maintain busy elective schedules, while spending some number of weeks per year on-call for the VACS service. Other models could consider dedicating certain surgeons specifically to VACS.

Given the economic pressures of the modern healthcare environment, resource allocation will be an important decision point for many hospital systems considering implementing a VACS service. As with any program, there will always be the question of how to best spend limited funding dollars. Certainly, 24/7 vascular surgeon coverage would be essential. Ideally, a dedicated staff of advanced practice providers, nurses, and operating room staff with specific knowledge and training in acute vascular issues would be advantageous. Dedicating resources to pre-hospital and referral services could potentially increase the acute vascular patient volume at centers needing a boost to justify their VACS services.

We believe that ultimately, an accreditation process establishing minimum criteria for levels of care for vascular surgery patients would follow. Triage of acute patients would improve as EMS understood what available resources exist at different institutions for acute vascular patients. Much as EMS knows that a patient in a high-speed motor vehicle collision needs to be seen at a level 1 trauma center, they could identify that a hypotensive patient with back pain and potential ruptured AAA would be best evaluated at a level 1 vascular center, rather than a smaller community hospital. A group in Minneapolis previously proposed integrating all cardio-vascular diseases into a "Cardiovascular Emergency Care System." [56] They proposed certification of certain centers based on available resources for cardio-vascular care. We believe this type of model could improve care for acute vascular patients. By establishing accreditation standards or tiers of care, patients could be better triaged to proper vascular care center. The data published by the Maryland group suggest that proper triage to a well-equipped Vascular center improves patient outcomes [51]. A hypothetical tiered system for Vascular Emergencies based on the trauma designation has been proposed and published recently (Fig. 9).

Future Directions

The Acute Care Surgery specialty has grown considerably since its inception in 2005 [34]. With their own society, literature, and fellowships, the field has established itself as an integral part of Surgery Departments worldwide. For Vascular Acute Care Surgery to succeed, it too will need to carve out a niche. Components of this will include the need to develop guidelines for standardization of VACS services. Consideration will have to be made for future training of VACS specialists. Additional fellowship training pathways for vascular surgeons interested in caring for acute vascular patients could improve and augment the skillset of recent graduates. For any systems change to be lasting, there has to be data to support its existence and drive improvement in its practices. As was the case in the ACS model development, implementation of VACS services should be followed by data collection an analysis of outcomes, aimed at improving protocols and patient care. Vascular acute care surgery patients will continue to arrive in emergency departments nationwide and Vascular Surgery as a specialty must be open to implementing novel ideas if it wishes to provide the highest level of care for these patients.

Limitations of the Model

Limitations of the Vascular Acute Care Surgery model include the potential for increased up-front costs and the need for sufficient patient volume to sustain the profitability of the service. Theoretically, the increased costs associated with developing a new hospital service would be offset by increased productivity due to specialization and liberalization of other vascular surgeons to perform elective procedures. Acute Care Surgery has proven to be economically beneficial and VACS can be reasonably expected to replicate those results.

In order to achieve the desired goals of improving patient care and reducing costs, Vascular Acute Care Surgery services will require regionalization of specific patients to specific centers. By funneling acute vascular patients to academic and other tertiary and quaternary referral centers with specialized Vascular Acute Care Surgery services, patient outcomes can be improved and economies of scale will help generate adequate hospital returns. This model is unlikely to succeed without adequate triaging of patients.

Table V. Potential emergency vascular care tiers and resource standards

Resource	Level III	Level II	Level I
Vascular staffing	Board-certified general or vascular surgeon	Board-certified vascular surgeons	Board-certified vascular surgeons In-house service coverage
Cardiovascular services	Basic open peripheral vascular Angiography and basic peripheral endovascular	Comprehensive peripheral and cerebrovascular RAAA capability Advanced peripheral endovascular Peripheral thrombolysis	Comprehensive peripheral and cerebrovascular capabilities Comprehensive peripheral endovascular capabilities Peripheral arterial/venous and pulmonary arterial thrombolysis Protocolized RAAA program with EVAR Thoracic and thoracoabdominal aorta program Carotid stenting Extracorporeal life support
Consultant services		Emergency general surgery	Emergency general surgery Cardiothoracic surgery Cardiovascular anesthesia Neurointerventional radiology
Transfer infrastructure	Arrangements to facilitate transfers to Level I or II	Arrangements to facilitate transfers to Level I Ability to rapidly receive and evaluate transfers from Level III	Structured referral and transfer program Aeromedical resources ICU-level transfer—receiving unit
On-call support services	OR team	Vascular laboratory technician Vascular OR team Radiology technician	Neuromonitoring technician Vascular laboratory technician Hybrid/vascular OR team Radiology technician
Operative and technical resources	Daytime endovascular capabilities 24-hr OR access CTA	24-hr endovascular capabilities 24-hr OR access Vascular laboratory CTA	24-hr hybrid OR access Spinal drain capabilities Intravascular ultrasound Cell saver Comprehensive endograft inventory Banked biologic conduit Endovascular coils Vascular laboratory CTA
Medical resources	ICU	ICU with RRT capability Blood bank	CT or surgical ICU with RRT capability Blood bank with capability for MTP
Education			Vascular surgery training program
Research/QI	Outcomes tracking and QI initiatives	Outcomes tracking and QI initiatives Surgical registry participation	Outcomes tracking and QI initiatives Surgical registry participation

EVAR, endovascular abdominal aortic repair; ICU, intensive care unit; OR, operating room; CTA, computed tomographic angiography; RRT, renal replacement therapy; CT, cardiothoracic; MTP, massive transfusion protocol; QI, quality improvement.

Fig. 9 A proposed emergency vascular care tier system. Reprinted from Harris et al. (2018) with permission from Elsevier

While VACS is a viable solution to the vascular surgery coverage crisis in suburban and urban healthcare systems, it is not clear whether small rural hospitals would directly benefit from VACS. VACS services may not make sense in hospital systems with just one or a few vascular surgeons at present. Additionally, it is unlikely that VACS would solve the shortage of vascular surgeons in rural communities.

Who Better to Care for These Patients?

The concerns expressed by Singh and others regarding the timely access to quality care for acute vascular patients in the Emergency Department are not going unnoticed by the Acute Care Surgery field [32•]. In some settings, trauma surgeons already perform a significant volume of vascular repairs and are reporting their cost-effectiveness in doing this work [57]. ACS surgeons are reporting that they are equally capable of performing limb salvage [58]. Endovascular interventions such as the resuscitative aortic balloon occlusion of the aorta (REBOA), which Acute Care Surgeons are learning in 2-day courses [59], may provide a springboard for efforts to learn more advanced endovascular techniques.

Conclusions

Vascular surgery is at a similar crossroads today as General Surgery was in the early 2000s. Data suggest vascular surgery trainees and practicing vascular surgeons gravitate towards predictable, well-compensated practices resulting in fewer surgeons available to provide acute vascular surgery services. The lack of acute vascular surgery care confers significant cost to patients, hospital systems, and payers. Similar to Acute Care Surgery service, a Vascular Acute Care Surgery (VACS) service stands to improve the quality of care delivery for critically ill patients, ensure surgeon coverage for acute vascular emergencies, and potentially provide an economic gain to hospitals.

Acknowledgement The editors would like to thank Dr. Anne Fischer for taking the time to review this manuscript.

Compliance with Ethics Guidelines

Conflict of interest Matthew Aizpuru, Aidan P. Sweeney, J. Devin Watson, Donald G. Harris, Charles B. Drucker, Jose J. Diaz, and Robert S. Crawford each declare no potential conflicts of interest.

Human and Animal Rights and Informed Consent This article does not contain any studies with human or animal subjects performed by any of the authors.

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- • Of importance
- •• Of major importance

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