

Training in vascular trauma surgery for non-vascular surgeons

Vascular trauma surgery skills course

M. Engelhardt · R. Schmid · B. Kölbel · A. Hyhlik-Dürr · S. Zerwes · C. Zischek

Summary

Background The experience of general and trauma surgeons in vascular trauma management has decreased with sub-specialization of surgery and working hours restrictions. We introduce a vascular trauma surgery skills course established to train German military surgeons prior to their deployment to conflict areas.

Methods The intention and implementation of the vascular trauma course for non-vascular surgeons is described in detail.

Results In hands-on courses, participants learn and train basic vascular surgical techniques on more realistic extremity, neck, and abdominal models with pulsatile vessels. A fundamental and an advanced course each provide military as well as civilian surgeons from different non-vascular specialties with a surgical skill set including direct vessel sutures, patch angioplasty, anastomosis, thrombectomy, and resuscitative endovascular balloon occlusion of the aorta (REBOA) in order to render them capable of managing major vascular injuries.

Conclusion The experiences of this vascular trauma surgical skills course, initially established for military surgeons, can also be of use to all civilian general, visceral, and trauma surgeons occasionally facing traumatic or iatrogenic vascular injuries. Thus, the introduced vascular trauma course is valuable for all surgeons working in trauma centers.

Keywords Vascular injury · Surgical technique · Simulation · Surgical training · Vascular training

Introduction

Major vascular injuries are uncommon in Europe, with an incidence of approximately 1–2% of all traumas [1, 2]. However, in settings with predominantly penetrating injuries, as is typical for combat situations and terror attacks, the incidence of vascular trauma increases dramatically. In urban districts with high violence, penetrating injuries make up for more than 75% of all vascular traumas [3, 4], and in modern wars, up to 12% major vascular trauma must be expected [5]. Not surprisingly, terror attacks are associated with vascular trauma similar to combat scenarios with an incidence 10% [6], and more than 50% of the critically injured victims of terror-related explosions encounter a vascular trauma [2].

Independent of their origin, most major vascular injuries have in common that they are life and limb threatening and usually require immediate surgical attention. Eastridge et al. analyzed US combat casualty death from the wars in Afghanistan and Iraq between 2001 and 2011 [7]. Of the pre-MTF (medical treatment facility) fatalities, 75.7% ($n=3040$) were classified as non-survivable and 24.3% ($n=976$) were deemed potentially survivable. The primary cause of these potentially survivable deaths was hemorrhage, at 90.9%. Therefore, immediate control of hemorrhage is paramount to reducing mortality. Furthermore, the golden hour for revascularization of the extremities lies within 6 to 8 h after the onset of ischemia [3, 8, 9], limiting the time for transportation or secondary transfer of patients with major vascular injuries.

The management of vascular trauma can be very challenging for even experienced surgeons and de-

M. Engelhardt (✉) · R. Schmid · B. Kölbel · C. Zischek
Department of Vascular and Endovascular Surgery, Centre
for Vascular Medicine, Military Hospital Ulm, Oberer
Eselsberg 40, 89081 Ulm, Germany
gefchir_bwkulm@yahoo.de

A. Hyhlik-Dürr · S. Zerwes
Medical Faculty, University of Augsburg, Augsburg, Germany

layed treatment can easily result in severe complications, limb loss, or death. While rapid treatment by a vascular specialist can usually be ensured in metropolises with a high density of vascular surgical departments, this might not necessarily be the case in rural areas or in the situation of mass casualties after explosion disaster or terror attack. In these situations, surgeons unfamiliar with vascular trauma might easily be confronted with severe vascular injuries, as well.

Vascular trauma surgical skills

As major vascular injuries require immediate surgical treatment for hemorrhage control and revascularization, all surgeons working in trauma centers should be familiar with basic vascular trauma surgical skills. However, surgical skills training on trauma patients is becoming more and more limited in clinical practice, due to working hours restrictions, especially in Europe [10, 11]. In addition, with vascular surgery evolving from a sub-specialty of general surgery to an independent specialty, and the increasing importance of endovascular procedures for the treatment of vascular injuries [12, 13], general surgeons will lose their expertise in vascular surgery more and more. As early as 15 years ago, Grabo et al. reported a dramatic downward trend of more than 30% in the number of major vascular procedures a general surgery resident performs within 10 years [14]. In the US, resident experience with vascular injuries is low and likely inadequate given a national average of only four vascular trauma cases performed per graduating resident, with fasciotomies and operations for peripheral vascular

trauma constituting the majority of these cases [15]. Some residents never experience exposure and repair of arteries in the abdomen, thorax, and neck. It must be expected that the situation is no better in Europe.

Vascular trauma surgery training course

In view of these recent developments in general surgery on the one hand and the high incidence of vascular injuries in modern wars on the other, the German Army Medical Service recognized that their general surgeons required additional training in vascular trauma surgery before going on military deployment. As it was obvious that these skills could not be learned and maintained within the scope of civilian surgical practice in the military hospitals in Germany, a special vascular trauma skills training program needed to be developed. In the preceding years, trauma surgery skills courses using simulation models had emerged as an effective alternative to overcome limited open operative experience [16]. Therefore, a vascular trauma surgery course for non-vascular surgeons using established vascular surgery simulation models was developed in cooperation with the Vascular International School, Switzerland [17, 18]. Meanwhile, this course is mandatory for every German military surgeon together with concomitant courses in damage control surgery (DCS) in anaesthetized swine and a course on surgical skills for exposure in trauma using human cadavers. Together, these courses aim to fill the gap in lacking proficiency in open surgical treatment for major vascular trauma.

Fig. 1 Two tutors explain and demonstrate the exercise step by step while the participants watch carefully on their monitors. Thereafter, each participant repeats the exercise under supervision of the tutors



The vascular trauma surgery skills program is divided into two separate courses: the basic course focuses on open vascular surgical techniques in general and extremity vascular trauma, while the advanced course concentrates on truncal and neck trauma. In each two-day course, seven tutors, all experienced vascular surgeons from major vascular surgery departments in Germany, Austria, and Switzerland, instruct no more than 24 participants, ensuring intensive feedback for each participant at all times. Each exercise is demonstrated and explained step by step by one of the tutors and the participants follow the demonstration on the monitors next to their workstations (Fig. 1). Thereafter, the participants perform the exercise themselves, closely observed and corrected, if necessary, by the tutors.

Both courses are performed in the Military Hospital in Ulm, Germany, in cooperation with the Vascular International School, Switzerland. The hands-on courses are based on the well-established setting and the life-like models developed by the Vascular International School. The value of these models with pulsatile vessels for improvement of surgical skills in vascular surgery has been proven [19, 20]. Deliber-

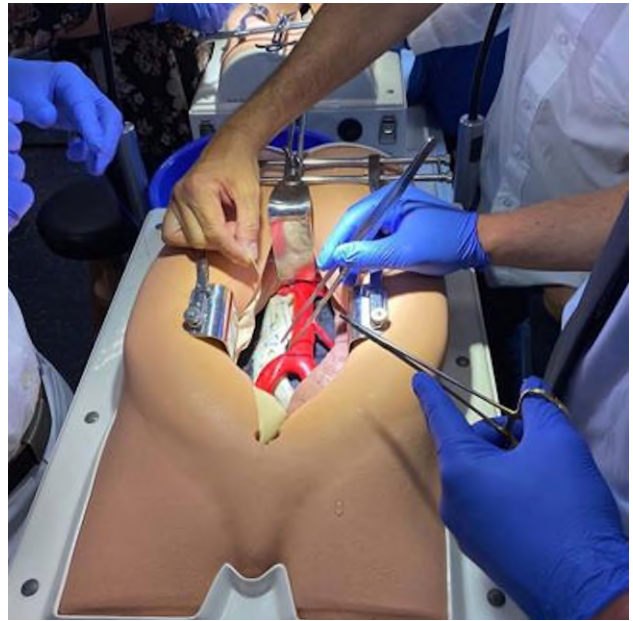


Fig. 3 A tutor giving tips for direct sutures of the inferior cava vein in the abdominal model



Fig. 2 Participants performing an interpositional graft in a box with pulsatile artery



Fig. 4 Participant performing an anastomosis to the supra-genual popliteal artery using a leg model. As in all Vascular International models, the artery has a pulsatile flow

ately, only few, easy-to-remember suture techniques are taught for direct sutures, patch angioplasty, and end-to-side and end-to-end anastomosis. Instead of introducing several different techniques, these few basic procedures are repeatedly performed by the participants, steadily increasing the level of difficulty from working in an open box (Fig. 2) up to performing an anastomosis deep in the abdomen (Fig. 3) or in an uncomfortable supragenual exposure of the leg (Fig. 4). Next to arterial and venous reconstructions with autologous and alloplastic grafts, adjacent techniques indispensable for vascular trauma management such as thrombectomy with a Fogarty catheter are introduced as well. Based on military requirements, a further focus lies on damage control surgery with direct suture techniques as well as placement and safe fixation of a temporary intravascular shunt. In addition to the dominating hands-on training, two brief lectures introduce special features of vascular trauma management and basic tactical considerations for the approach of these severe injuries.

As the course intends to give all surgeons, irrespective of their specialization, a vascular surgical tool kit easily available in every situation, it concentrates on open vascular surgery. The only endovascular technique introduced in the advanced course is resuscitative endovascular balloon occlusion of the aorta (REBOA), as practical knowledge of this procedure is mandatory for all military surgeons and frequently asked for among civilian trauma surgeons. The participants learn vascular access via inguinal puncture, placement, and handling of the balloon as well as the indications for and complications of REBOA [21].

At the end of every course the participants have to complete an evaluation form (Table 1). The vast majority of participants feel more confident and well prepared for daily practice, deployment, or work in a trauma center. Most participants would recommend the course to colleagues and voted for a repetition every 3 years. However, the benefit of the latter approach has not yet been proven and is subject to an ongoing study reevaluating the skills after several years. The main criticism of the courses is the missing training in vascular surgical exposure. However, this important aspect is element of another course.

Table 1 Results of the structured, anonymous feedback of all courses from 2018 to 2022 ($n=138$). During the COVID-19 pandemic the courses were temporarily paused. (Results are graded from “1 = I totally agree” to “5 = I totally disagree”)

Questions	Grade (Mean ± SD)
More confidence for daily practice	1.2 ± 0.44
More confidence for deployment	1.3 ± 0.48
Recommend training to colleagues	1.0 ± 0.15
Recommend repetition of training after 3 years	1.4 ± 0.69
Recommend training before deployment	1.6 ± 0.91

Impact on civilian trauma surgery

In the wake of several terror attacks in Europe in the past 20 years and given the decreasing experience in vascular trauma surgical skills among non-vascular surgeons, the interest in vascular trauma skills training has increased significantly among civilian surgeons as well. The experience from the terror attacks in Paris 2015, where 20 victims with severe non-thoracic vascular injuries were treated in eight hospitals throughout Paris with vein bypass (58%), patch angioplasty (6%), ligation (12%), or embolization (24%) [22], demonstrates the need for immediate vascular trauma expertise in such an exceptional situation and stresses the importance of a basic level of experience in vascular trauma management among all surgeons working in trauma centers.

As a response to this increasing interest among civilian general and trauma surgeons, the vascular trauma surgery course is not restricted to military surgeons before deployment, but addresses all surgeons who might be involved in traumatic or iatrogenic vascular injury management. Meanwhile, more than 350 civilian and military surgeons from different specialties, i.e., trauma, visceral, and thoracic surgery, urology, gynecology, ENT, and plastic surgery, from more than 15 different countries, have successfully participated in the course performed at the Military Hospital in Ulm, Germany. From 2016 to 2019 the course was additionally performed at the Ecole du Val-de-Grâce in Paris for the military surgeons of the French Army, and for 2023, a pilot course is planned for the German Society for Orthopaedics and Trauma Surgery (*Deutsche Gesellschaft für Orthopädie und Unfallchirurgie* [DGOU]) in the facilities of the Academy for Trauma Surgery (*Akademie für Unfallchirurgie* [AUC]) in Munich, Germany.

Conclusion

Despite the inevitable specialization in surgery, every surgeon concerned with trauma patients should possess basic skills in vascular trauma surgery. The vascular trauma surgery training course introduced here is able to provide non-vascular surgeons with a basic skill set for the management of traumatic and iatrogenic vascular injuries. The profound experience in the training of military surgeons can be of use for the development of training programs for civilian general and trauma surgeons.

Author Contribution All authors read and approved the final version of the manuscript. ME and AH had the idea of the article and drafted the manuscript. RS, BK, SZ, and CZ performed the literature search and critically revised the work.

Conflict of interest M. Engelhardt, R. Schmid, B. Kölbl, A. Hyhlik-Dürr, S. Zerwes and C. Zischek certify that there are no conflicts of interests and no competing interests with any

financial organization or companies regarding the material discussed in the manuscript.

References

1. Barmpara G, Inaba K, Talving P, et al. Pediatric vs adult vascular trauma: a nation trauma databank review. *J Pediatr Surg*. 2010;45(7):1404–12. <https://doi.org/10.1016/j.pedsurg.2009.09.017>.
2. Heldenberg E, Givon A, Simon D, Bass A, Almogy G, Peleg K. Civilian casualties of terror-related explosions: the impact of vascular trauma on treatment and prognosis. *J Trauma Acute Care Surg*. 2016;81(3):435–40. <https://doi.org/10.1097/TA.0000000000001123>.
3. Franz RW, Shah KJ, Halaharvi D, Franz ET, Hartman JE. A 5-year review of management of lower extremity arterial injuries at an urban level I trauma center. *J Vasc Surg*. 2011;53(6):1604–10. <https://doi.org/10.1016/j.jvs.2011.01.052>.
4. Bowley DMG, Degiannis E, Goosen J, Boffard KD. Penetrating vascular trauma in Johannesburg, South Africa. *Surg Clin North Am*. 2002;82(1):221–35. [https://doi.org/10.1016/S0039-6109\(03\)00151-8](https://doi.org/10.1016/S0039-6109(03)00151-8).
5. White JM, Stannard A, Burkhardt GE, Eastridge BJ, Blackburne LH, Rasmussen TE. The epidemiology of vascular injury in the wars in Iraq and Afghanistan. *Ann Surg*. 2011;253(6):1184–9. <https://doi.org/10.1097/SLA.0b013e31820752e3>.
6. Heldenberg E, Givon A, Simon D, Bass A, Almogy G, Peleg K. Terror attacks increase the risk of vascular injuries. *Front Public Health*. 2014;2:47. <https://doi.org/10.3389/fpubh.2014.00047>.
7. Eastridge BJ, Mabry RL, Seguin P, et al. Death on the battlefield (2001–2011): implications for the future of combat casualty care. *J Trauma Acute Care Surg*. 2012;73(6):S431–7. <https://doi.org/10.1097/TA.0b013e3182755dcc>.
8. Fox N, Rajani RR, Bokhari F, et al. Evaluation and management of penetrating lower extremity arterial trauma: an eastern association for the surgery of trauma practice management guideline. *J Trauma Acute Care Surg*. 2012;73(5):S315–20. <https://doi.org/10.1097/TA0b013e31827018e4>.
9. Jagdish K, Paiman M, Nawfar A, et al. The outcomes of salvage surgery for vascular injury in the extremities: a special consideration for delayed revascularization. *Malays Orthop J*. 2014;8(1):14–20. <https://doi.org/10.5704/MOJ.1403.012>.
10. Lamont PM, Scott DJ. The impact of shortened training times on the discipline of vascular surgery in the United Kingdom. *Am J Surg*. 2005;190(2):269–72. <https://doi.org/10.1016/j.amjsurg.2005.05.025>.
11. Bruce PJ, Helmer SD, Osland JS, Ammar AD. Operative volume in the new era: a comparison of resident operative volume before and after implementation of 80-hour work week restrictions. *J Surg Educ*. 2010;67(6):412–6. <https://doi.org/10.1016/j.surg.2010.05.007>.
12. Burkhardt GE, Rasmussen TE, Propper BW, Lopez PL, Gifford SM, Clouse WD. A national survey of evolving management patterns for vascular injury. *J Surg Educ*. 2009;66(5):239–47. <https://doi.org/10.1016/j.surg.2009.09.007>.
13. Engelhardt M, Orend K-H. *Gefäß- und Thoraxverletzungen*. Berlin, Boston: De Gruyter; 2021. pp. 79–140.
14. Grabo DJ, DiMuzio PJ, Kairys JC, McIlhenny SE, Crawford AG, Yeo CJ. Have endovascular procedures negatively impacted general surgery training? *Ann Surg*. 2007;246(3):472–80. <https://doi.org/10.1097/SLA.0b013e3181485652>.
15. Yan H, Maximus S, Koopmann M, et al. Vascular trauma operative experience is inadequate in general surgery programs. *Ann Vasc Surg*. 2016;33:94–7. <https://doi.org/10.1016/j.avsg.2016.02.005>.
16. Mackenzie CE, Tisherman SA, Shackelford S, Sevdalis N, Elster E, Bowyer MW. Efficacy of trauma surgery technical skills training courses. *J Surg Educ*. 2019;76(3):832–43. <https://doi.org/10.1016/j.jsurg.2018.10.004>.
17. Engelhardt M, Elias K, Friemert B, Klemm K, Willy C. Vascular surgical training concept for military surgeons in Germany. *Unfallchirurg*. 2018;121(7):544–9. <https://doi.org/10.1007/s00113-018-0485-8>.
18. Vascular International School. <https://vascular-international.org>.
19. Duschek N, Assadian A, Lamont PM, et al. Simulator training on pulsatile vascular models significantly improves surgical skills and the quality of carotid patch plasty. *J Vasc Surg*. 2013;57(4):1148–54. <https://doi.org/10.1016/j.jvs.2012.08.109>.
20. Wilhelm M, Klemm K, Assadian A, et al. Improve your skills!: evaluation of a 2.5-day basic course in vascular surgery for surgical trainees. *Chirurg*. 2013;84(2):125–9. <https://doi.org/10.1007/s00104-012-2395-6>.
21. Wortmann M, Engelhardt M, Elias K, Popp E, Zerwes S, Hyhlik-Dürr A. Resuscitative endovascular balloon occlusion of the aorta (REBOA). *Chirurg*. 2020;91(11):934–42. <https://doi.org/10.1007/s00104-020-01180-0>.
22. Tresson P, Touma J, Gaudric J, et al. Management of vascular trauma during the Paris terrorist attack of November 13th, 2105. *Ann Vasc Surg*. 2017;40:44–9. <https://doi.org/10.1016/j.avsg.2016.09.011>.