Simulation-Based Training in Vascular Procedures

Jack A. Kastelik MD[1], Rooshan Qaiser[2]

1. Medical Education Centre, Hull University Teaching Hospitals NHS Trust, Hull Royal Infirmary, Anlaby Road, Hull, HU3 2JZ
2. Department of Respiratory Medicine, Hull University Teaching Hospitals NHS Trust, Hull Royal Infirmary, Anlaby Road, Hull, HU3 2JZ

Corresponding Author:
Professor Jack Kastelik jack.kastelik@nhs.net

Background

Simulation has become an essential aspect of vascular surgical training. It provides a progressive, risk-free environment for the acquisition and refinement of procedural skills. Different simulation modalities are tailored to the learner's level of experience and learning goals. They can be categorised into task trainer simulation, high fidelity and wet Lab simulation, cadaveric simulation, and Virtual and Extended Reality (VR/XR) simulation. Task training simulation allows for the creation of a simple teaching model, which will allow the trainers to deliver a standardised teaching approach and for the trainees to achieve a sustainable outcome[1]. Task training is fundamental for early-stage training, allowing repetitive practice of core procedures such as ultrasound-guided cannulation, arterial blood gas (ABG) sampling, and suturing. These low-fidelity models are ideal for building procedural confidence and technical accuracy. High-fidelity simulation is a cutting-edge pedagogical tool that utilises full-scale computerised simulators to replicate real-world clinical scenarios[2,3]. Wet lab animal models and high-fidelity simulations are targeted at mid-grade trainees. These focus on improving precision in dissection, tissue handling, and anastomotic skills, while encouraging the development of surgical economy of movement and coordination.

Such training enhances confidence and technical fluency before exposure to complex operative settings.

Cadaver-based sessions are designed for advanced trainees with a solid grounding in anatomy and procedural basics[4]. These simulations offer unparalleled realism in tissue handling, vascular dissection, vessel control, and anastomotic technique. They serve as a vital transition between simulated and operative environments, enhancing anatomical orientation and operative fluency. Extended reality (XR), here jointly referring to virtual, augmented, and mixed reality has become more widely used in medical education[5]. VR and XR technologies are increasingly used in vascular surgery, particularly for endovascular procedures. High-fidelity simulators allow realistic manipulation of wires, catheters, and stents in virtual patient anatomies. They simulate real-time physiological responses, aiding in the understanding of stent deployment, device navigation, and management of aortic pathologies[6]. These technologies are invaluable for both pre-operative planning and procedural training. Another aspect of simulation would be through the use of standardised patients (SPs), which offers an authentic, patient-centred simulation experience[7]. These diverse simulation strategies form a comprehensive structure for vascular training, ensuring a robust foundation in technical skills while fostering clinical reasoning, confidence, and patient safety across all stages of development. Simulation-based learning has increasingly been adopted in healthcare training due to its ability to provide safe, repeatable practice. Previous studies have validated its effectiveness in improving learner performance and patient safety[8]. In this report we describe our experience in organising a dedicated vascular skills simulation training course.

Description of the Vascular Procedures Course

A designated vascular procedures simulation course was designed to facilitate foundation doctors to gain experience in ultrasound guided cannulation, ankle-brachial pressure index (ABPI) measurements, knot tying and suturing. As part of the simulation course the participants completed a feedback form, which addressed issues of knowledge, confidence and readiness to perform each vascular surgical skill as well as open-text reflections. This evaluation form was part of the course and helped the participants in understanding of their learning as well as providing the trainers with feedback.

The vascular procedures simulation course included four skill stations: (1) ultrasound-guided cannulation, (2) ABPI measurement, (3) knot tying, and (4) suturing. The simulation day was structured around four core stations, each designed to target specific procedural competencies. Stations were delivered in timed rotations with focused supervision, demonstration, and hands-on practice. Below is a breakdown of each station's setup and instructional content:

1. Ultrasound-Guided Cannulation

This station used upper limb vascular phantoms with simulated venous drainage and portable ultrasound machines to offer a lifelike procedural environment. Instruction included a lecture and video demonstration to explain key principles, followed by hands-on practice. Trainees were taught to assess probe angle and orientation, differentiate arteries from veins on crosssectional imaging (based on compressibility, pulsatility, and Doppler flow), and interpret direction of blood flow. Emphasis was placed on needle visualisation in both transverse and longitudinal views, maintaining in-plane imaging, and confirming vessel entry with real-time ultrasound feedback.

2. ABPI Measurement

Trainees used a manual sphygmomanometer, handheld Doppler probe, and standardised patients to replicate real-world clinical scenarios. This station focused on measuring systolic pressures at the brachial and ankle levels, identifying key Doppler waveforms (triphasic, biphasic, monophasic), and calculating ankle-brachial pressure indices accurately. The session was preceded by a video tutorial and audio clips of Doppler sounds to train learners in waveform recognition and diagnostic interpretation. During our skills day, the ABPI station was conducted using standardised patients, enabling trainees to perform Doppler assessments and calculate ankle-brachial pressure indices in real-time. This approach enhanced learners' appreciation of clinical variability, waveform interpretation, and patient interaction, thereby promoting both technical and communication competencies.

3. Knot Tying

A tabletop station using synthetic tubing allowed trainees to practice various knot techniques. Demonstrations covered slip knots, surgeon's knots, and reef knots, with supervised repetition to build consistency and reliability in knot security. Emphasis was placed on hand positioning, suture tension control, and speed of execution without compromising accuracy.

4. Suturing

Using synthetic skin pads and monofilament non-absorbable sutures, this station trained participants in four primary suturing techniques: simple interrupted, simple continuous, horizontal mattress, and vertical mattress. Instruction focused on correct needle holder grip, needle-tissue entry angle, wrist and hand movement economy, and gentle tissue handling to prevent trauma. Faculty provided real-time corrections and reinforced ergonomic techniques to promote long-term surgical efficiency.

This structured approach allowed for concentrated skill-building and immediate feedback, enabling a robust and engaging learning experience tailored to trainee needs.

A cohort of 16 trainees participated in a vascular simulation day. The participants feedback revealed improvement in knowledge, confidence, and readiness to perform independently each skill. Improvements were especially notable in ABPI performance. The ultrasound-guided cannulation was the most valuable skill and the knot tying and suturing were perceived as most challenging. Participants felt that they gained greater confidence and preparedness for clinical practice following the course.

Discussion

Simulation forms an important part in medical and surgical training. Simulation allows for interactive and immersive educational activity through recreation of clinical experience[9,10].

Simulation allows trainees to learn theoretical and technical skills before performing procedures on patients[9-11]. Educational technology relates to facilitation of learning through the utilisation of technological processes and resources that would incorporate the use of software, hardware, internet and simulators[12]. Educational technology including simulation may have potential applications for training in vascular surgical skills. Simulation training days are tailored to these advanced skills using appropriate modalities such as cadaveric dissections, wet labs, and high-fidelity VR platforms, depending on the procedure's complexity and the trainee's experience. During the vascular procedures course, trainees felt that they gained confidence and readiness in stations such as ultrasound-guided cannulation and knot tying. In addition, the training in ABPI skills was very valuable.

Vascular surgical training follows structured progression from foundational skills to advanced procedural competence[13]. The curriculum is structured to align with the stage of training and procedural complexity. At Foundation and Core Level Curriculum the focus is on developing fundamental surgical skills and anatomical awareness. Key learning objectives include identification of surface and deep anatomical landmarks for incision planning, safe tissue handling and dissection techniques, proficiency in tying secure knots, including slip, surgeon's, and reef knots, performing basic suturing techniques with attention to instrument handling and tissue preservation. Once proficiency in these core competencies is demonstrated, trainees may progress to more complex skills such as performing a basic vascular anastomosis under supervision. Simulation-based training supports this progression by offering structured, risk-free practice environments. Higher surgical trainees are expected to perform the above skills with increasing autonomy and precision[14]. Additional competencies include achieving vascular control and applying clamps safely, performing vessel access, repair, and anastomosis using both autologous tissue and prosthetic grafts, planning and executing entire vascular procedures across a range of anatomical regions.

The vascular procedures catalogue encompasses both open and endovascular surgeries across anatomical regions including neck and upper limb arteries, thoracic and abdominal aorta, visceral and renal vessels, supra- and infra-inguinal bypasses, extra-anatomical bypasses, vascular access for dialysis, major and minor limb amputations. Each of these procedures represents an integration of multiple discrete skills developed progressively over a decade of surgical training, from foundation to core to higher specialty levels, culminating in readiness for independent practice as a consultant. Simulation methods are strategically selected based on trainee level, procedural complexity, and learning objectives. Simulation was highly effective in improving all assessed domains. Qualitative data aligned with statistical outcomes, reinforcing the value of immersive, hands-on training. Future sessions could offer extended time for suturing and knot tying.

In conclusion, we described our experience of developing and delivering a designated basic vascular skills simulation training course. Our experience suggests that a simulation course can be used for training in basic vascular surgical skills. The course helped the trainees to gain practical knowledge and confidence to perform basic vascular surgery skills in simulation settings.

References

1. Singh M, Restivo A. Task Trainers in Procedural Skills Acquisition in Medical Simulation. [Updated 2023 May 1]. In: StatPearls. Treasure Island (FL): StatPearls Publishing; 2025 Jan-. Available from: https://www.ncbi.nlm.nih.gov/books/NBK558925/
2. Carey JM, Rossler K. The How When Why of High Fidelity Simulation. [Updated 2023 May 1]. In: StatPearls [Internet]. Treasure Island (FL): StatPearls Publishing; 2025 Jan-Available from: https://www.ncbi.nlm.nih.gov/books/NBK559313/
3. Roberts E, Kaak V, Rolley J. Simulation to replace clinical hours in nursing: a meta-narrative review. Clin Simul Nurs 2019; 37; 5-13. 10.1016/j.ecns.2019.07.003
4. J.I Fann, AD Caffarelli, G Georgette, SK Howard, DM Gaba, P Youngblood, RS Mitchell, TA Burdon. Improvement in coronary anastomosis with cardiac surgery simulation J. Thorac Cardiovasc Surg 2008; 136 (6) 1486-1491
5. Vasarainen M, Paavola S, Vetoshkina L. A Systematic Literature Review on Extended Reality: Virtual, Augmented and Mixed Reality in Working Life. Int J Virtual Reality 2021; 21 (2) 1-28
6. McGaghie WC, Issenberg SB, Cohen ER, Barsuk JH, Wayne DB. Does simulation-based medical education with deliberate practice yield better results than traditional clinical education? Acad Med. 2011;86(6):706-711.
7. Hillier M, Williams TL, Chidume T. Standardization of Standardized Patient Training in Medical Simulation. [Updated 2023 Jul 24]. In: StatPearls. Treasure Island (FL): StatPearls Publishing; 2025 Jan-. Available from: https://www.ncbi.nlm.nih.gov/books/NBK560864/

8. Issenberg SB, McGaghie WC, Petrusa ER, Gordon DL, Scalese RJ. Features and uses of high-fidelity medical simulations that lead to effective learning: a BEME systematic review. Med Teach. 2005;27(1):10-28.
9. Scalese RJ, Obeso VT, Issenberg SB Simulation technology for skills training and competency assessment in medical education. J Gen Intern Med 2008; 23 Suppl 1 46-49
10. Flanagan J, Baldwin S, Clarke D. Work-based learning as a means of developing and assessing nursing competence. J Clin Nurs 2000; 9(3) 360-368
11. Choy I, Okrainec A. Simulation in surgery: perfecting the practice. Surg Clin North Am 2010 90(3) 457-473
12. Meier AH, Rawn CL, Krummel TM Virtual reality: surgical application--challenge for the new millennium. J Am Coll Surg 2001; 192(3) 372-384
13. Vascular surgery curriculum. https://www.gmc-uk.org/education/standards-guidance-and-curricula/curricula/vascular-surgery-curriculum
14. Vascular surgical curriculum. scp.ac.uk/iscp/curriculum/vascular-surgery-curriculum/2-purpose/#:~:text=The%20curriculum%20covers%20the%20three,having%20been%20appointed%20at%20ST1