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ORIGINAL ARTICLE

Simulation in vascular access surgery training

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ABSTRACT

Rapidly growing technical developments and working time constraints call for changes in trainee formation. In reality, trainees spend fewer hours in the hospital and face more difficulties in acquiring the required qualifications in order to work independently as a specialist. Simulation-based training is a potential solution. It offers the possibility to learn basic technical skills, repeatedly perform key steps in procedures and simulate challenging scenarios in team training. Patients are not at risk and learning curves can be shortened. Advanced learners are able to train rare complications. Senior faculty member's presence is key to assess and debrief effective simulation training. In the field of vascular access surgery, simulation models are available for open as well as endovascular procedures. In this narrative review, we describe the theory of simulation, present simulation models in vascular (access) surgery, discuss the possible benefits for patient safety and the difficulties of implementing simulation in training.

Keywords: Education, Simulation, Team training, Training, Vascular access surgery

Introduction

The surgical craft is undergoing a steady process of adaptation to new technological developments. Under the aspect of being a demanding profession, which includes highly complex psychomotor activities in the operating room, surgeons are under constant pressure to reach excellence in their duties (1). However, an analysis of operative logs from graduating chief residents in general surgery in the United States showed a lack of operative experience for many essential procedures (2). This is linked to low training hours spent in the operating room. Similar issues of limited time resources apply to Europe due to the European Working Time Directive (3, 4).

Focussing on vascular surgery, an increase in endovascular interventions along with stable numbers of open procedures has been reported (5). The rapidly changing field of endovascular devices and procedures asks for access to learning opportunities. Vascular access creation is still a domain of open surgery but in complex situations (e.g. access revisions) endovascular procedures are vital. Therefore, aspiring vascular (access) surgeons face a wide range of different procedures that they have to master within a limited time. This trend, together with technical innovations of vascular access devices, is calling for training models. Simulation is an essential piece of the puzzle in order to achieve excellence in surgical specialty.

In the following article, we demonstrate the use of simulation and team training in vascular (access) surgery training and its contribution to patient safety.

Underlying theory of simulation

The idea of simulation in medical education originates from research in other professions (e.g. training of pilots in aviation). Furthermore, research in music showed that professional pianists were separated from amateur musicians by their amount of training, which exceeded 10,000 hours of practice (6). But even expert musicians who spent similar amount of time in all types of music-related training could be distinguished by their performance, associated with the amount of time spent in solitary practice. This is where difficult parts of a musical piece can be practised to a great extent. The same principle applies to surgical procedures where complex parts should be trained repeatedly, without the need to perform the whole operation, to reach and maintain expert performance (7). Deliberate practice includes the motivation to improve performance through regularly repeated similar tasks, build on existing knowledge and followed by immediate informative feedback (8). This form of practice helps juniors to become experts and experts benefit from the possibility to train rare conditions such as intraoperative complications and emergency procedures.

In the 1990s first laparoscopic simulators were used to exercise technical operative skills. Today laparoscopic surgery simulators are widely available, ranging from low-fidelity box

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trainers to computer-based virtual reality simulators where different cases can be trained. Laparoscopic surgical box model training seems to be of value for surgical trainees with no previous experience (9). Laparoscopic surgery virtual reality training for trainees with limited experience is decreasing operating time and improving operative performance (10).

The skills transferability from surgical simulation into the operating room is still debated depending on the parameters measured (11, 12). Quantifiable skills in the laboratory setting, such as time to completion and Objective Structured Assessment of Technical Skills (OSATS) scores, could be reproduced in the operating room. But these measurements may not be sufficient to demonstrate a trainee's ability to perform a procedure safe and with the required quality.

Types of simulation models

Simulators can be divided into different modalities and models, with a varying degree of fidelity. The modality refers to the skills, which are addressed with simulation, for example, suturing and knot tying or anastomotic techniques. Manufacturers offer different models to train each modality. The degree to which these models reflect the real-life experience in the operating room is called the model's fidelity (13).

Available simulators in the field of vascular surgery are listed in Table I. Simple anastomoses suturing bench models, using tube grafts as vessels, are an inexpensive way of simulation, targeting medical students and junior trainees to raise interest in vascular surgery. A higher fidelity in arterial anastomoses bench models contributes to better skill transfer to live animals (13). Advanced learners generally require simulation models with a higher degree of authenticity. Fresh cadavers are an alternative for learning basic open vascular surgery principles (14) helping to conceptualize troublesome anatomic relationships such as common iliac artery bifurcations or supra-aortic branches (15).

TABLE I - Simulation modalities and models in vascular surgery training

Modality		Models
Basic skills	Anatomy	Complex anatomic relationships in cadavers (15)
	Anastomoses	Vascular anastomoses training with bench model (plastic tubes or cadavers) (13, 14)
Open vascular procedures	Venous	Vein patch (17)
	Arterial	Pulsatile flow models for legs, abdomen and neck (16)
	Vascular access	Venous puncture simulation (20), pulsatile arm model to create vascular access (19)
Endovascular procedures	Arterial	Pulsatile endovascular flow models for endovascular aneurysm repair (EVAR), thoracic endovascular aortic repair (TEVAR) or carotid artery stenting (16)
	Vascular access	Vascular access angiogram, balloon angioplasty and stent placement (20)
Virtual reality operating room		Carotid endarterectomy in a simulated operating room (22)

Fig. 1 - Experienced tutors train young surgeons in performing anastomoses on cadavers.

The European Vascular Course Committee (www.vascular-course.com) and the European Society of Vascular Surgery (www.esvs.org) have been offering vascular access workshops for several years (Fig. 1). The Vascular International Foundation and School (www.vascular-international.org) is conducting vascular surgical training since 1991 with a wide range of different models (16-18). Their lifelike pulsatile flow models cover open as well as endovascular procedures.

A new pulsatile arm model (Fig. 2), which has been presented at the Charing Cross Symposium 2013 for the first time, can be used to perform more than eight different vascular access procedures (19). Simulation possibilities for percutaneous intervention, ultrasound-guided cannulation and team training in vascular access surgery have been described previously (20). The new arm model fills an important gap in vascular access training opportunities and altogether could form the basis to train multidisciplinary teams taking care of patients with end-stage renal disease.

The virtual reality operating room is situated at the top of simulation fidelity. It has great potential as a learning environment for junior and senior surgical trainees alike (21). Although it requires immense resources, a simulated operating theatre could be used for example to assess competency in carotid endarterectomy surgery (22). In this study, a significant difference emerged between junior and senior trainees' technical and non-technical skills in crisis and non-crisis scenarios where professional actors imitated a stroke at defined times during the procedure.

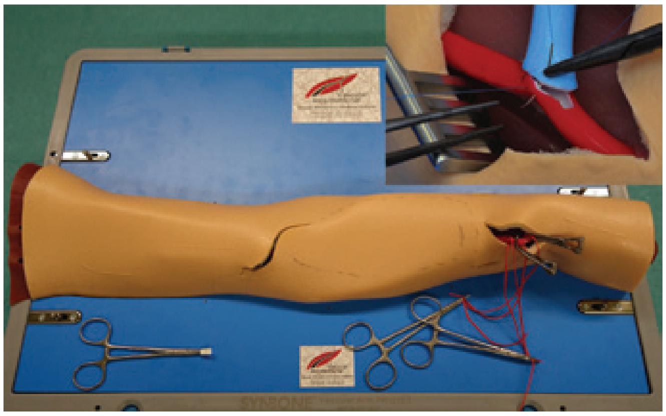

Fig. 2 - New pulsatile arm model: options for more than eight different vascular access procedures.

Trainee assessment

Apart from finding the time for simulation and having the right simulator for an appropriate level of surgical skills it is crucial to assess the performance and to provide accurate feedback. The OSATS instrument is used to assess surgical skills, although only scarcely validated for its use in the operating theatre (23). First described in 1997, the OSATS consists of a task-specific checklist, a detailed global rating scale and a pass/fail judgement (24). A prospective multicentre study investigated the validity and reliability of a modified OSATS instrument designed for use in the operating room (25). The modified instrument consists of a global rating scale, an overall performance scale, an alphabetic summary scale and space for a written feedback. The authors report its potential for monitoring resident's progress in operative competence.

To overcome subjectivity, which persists in all checklists, hand motion analysis could be an additional tool to assess surgeons. In a vein patch insertion bench-top model with synthetic vessels a decrease in the number of movements and the time to complete the task could be shown with increasing operator experience (26). Assessment tools in vascular surgery training have been systematically reviewed (27). Most tools are focused on technical skills and none is comprehensive enough to serve for a wider use in open and endovascular procedures as well as to assess technical and non-technical skills.

Every simulation session should be evaluated and debriefed afterwards to maximize the educational benefit (28, 29). We believe that assessment and debriefing are two major factors, which found the success of simulation in today's surgical training. These tasks are often neglected in a busy patient-centred working routine as opposed to a learner-centred environment within simulation.

Patient safety and team training

There is plenty of published evidence to support the benefits of simulation on technical skills. But the more important endpoint in evaluating simulation is the patient. Schmidt et al reviewed the literature and concluded that simulation may enhance patient safety through increase in technical, procedural and team performance (30). It allows physicians to train in a safe environment without setting patients at risk. This is also a crucial requirement when implementing new technologies or procedures in senior physicians. Simulated operating rooms offer a safe environment to train not only technical skills but also human factors (31). Surgeons can be exposed to exceptionally demanding situations, which are rare in daily training. Crisis management can be assessed, for example, a stroke during carotid endarterectomy (22).

In vascular access three key points are described to train the multidisciplinary team involved in patient care: knowledge improvement, skills and social intelligence training (20). A step further towards patient safety in vascular access surgery is the implementation of procedure-specific checklists including team member identification, patient details, site of operation, scheduled procedure, expected difficulties and required instruments. Certification requirements can further increase quality in training (32). This is a possibility to set certain standards in patient care and to harmonize vascular access curricula.

Implementation in daily work and educational curricula

Despite growing research in simulation, there is still great potential for wider implementation in surgical training (33, 34). Time and money constraints are frequent issues in including simulation in surgical training. Furthermore, senior faculty members, who are key for assessment and debriefing skills, are infrequently available and contribute to higher expenses as well (35). Recommendations for the development and implementation of simulation-based learning in surgical training are available (36, 37). It is of importance that training meets the learner's level of knowledge and skills, is supported by dedicated faculty members and that training sessions are assessed and followed by a debriefing. It is helpful to run realistic cases and stressors can be integrated to challenge different learners. Simulation should therefore be a mandatory part of trainees' clinical training and used regularly to avoid a decline in skills (38).

A possible approach to increase a resident's commitment in simulation training is to introduce tournaments with leaderboards and prizes (39). As a result, participants recognize their performance in direct comparison with peers and get motivated by a possible reward of their efforts. These concepts, called gamifications, originate from the computer game industry and aim at addicting players. Additionally, dedicated working time to spend in a simulation environment would further help to raise trainees' availability and interest and simultaneously adhere to mandatory working time directives.

Summary

In our opinion the evidence to support simulation as a tool to improve technical skills in surgical procedures, vascular access creation included, is convincing. The next important step is to demonstrate the superiority of simulation and daily operating room experience over operating room training alone on patient outcome. This is needed to justify the costs for

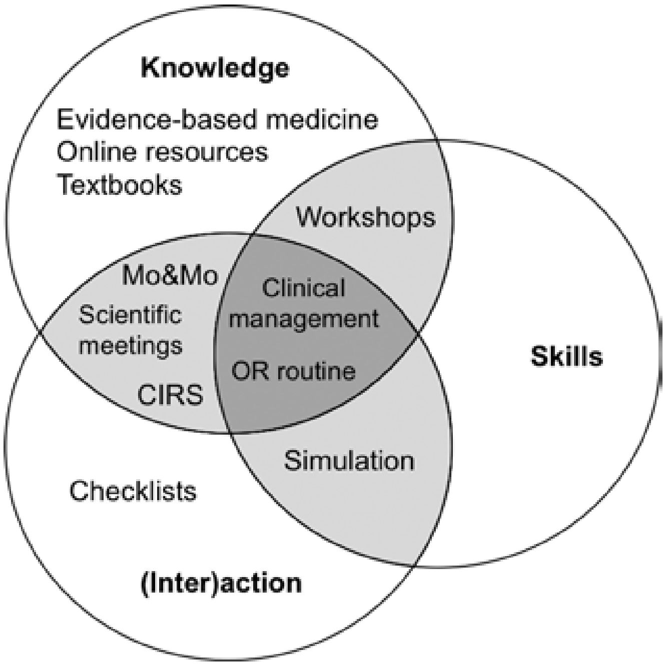

Fig. 3 - Vascular access surgery training separated into three competencies. Mo&Mo = mortality and morbidity conference; OR = operating room; CIRS = critical incidence reporting system.

high-fidelity simulation, such as computer-based simulators or virtual operating rooms. Senior faculty's time investments for simulation should be considered for future planning and cost calculations.

We believe simulation offers great advantages in training, for example, to repeatedly train specific steps in a procedure without setting a patient at risk. Skills, knowledge and the ability to (inter)act are three main competencies of a vascular surgeon. These areas can be trained through different options and to a different extent as presented in Figure 3. Skill means technical skills, knowledge is the background information about diseases and procedures and the ability to (inter) act includes decision making and non-technical skills such as communication. Daily clinical routine with training in the operating room and patient management covers all three areas. Simulation was originally focused on skills training. However, within a workshop knowledge should be added and with newer designs of simulated environments the ability to (inter)act is targeted in simulation as well.

Research should be driven to establish an internationally accepted tool to assess trainees in simulation as well as in the operating room. A variety of different simulators for vascular (access) surgery is needed to master the wide range of procedures covered by a vascular specialist. Therefore, further implementation of simulation in vascular training is desirable. Probably large national skill centres, supported by several departments from different hospitals, to cover the costs and to guarantee an acceptable utilization are an option. Such skill centres would offer the ability to engage learners through comparison with peers. Team training in simulated reality will hopefully increase in all stages of training, from medical students to senior surgeons, and improve patient safety.

Implementation in daily routine is difficult. Teaching should be acknowledged as much as research activities are. This is important because faculty serve as role models for trainees. Both should have sufficient time to devote to simulation.

Conclusion

Simulation-based vascular access training is and will be important. Efforts to support wider usage and implementation in daily clinical routine should be undertaken to train future vascular surgeons.

Disclosures

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