The role of simulation in Endovascular Aneurysm Repair (EVAR) training: a preliminary study

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What this study adds

Endovascular surgery requires a different skillset compared to open traditional surgical techniques. Acquiring this skillset can be challenging, costly and time consuming. Virtual reality simulation has recently been introduced in surgery with encouraging results. This study confirms that virtual reality based simulation in endovascular surgery can improve several aspects of trainee performance and contribute to patient safety. It should strongly be considered as part of structured vascular training in the future.

ABSTRACT

Background: Endovascular Aneurysm Repair (EVAR) requires a high-level of technical competency to avoid device-related complications. Virtual reality simulation based training (SBT) may offer an alternative method of psychomotor skill acquisition; however, its role in EVAR training is undefined. This study aimed to: a) benchmark competency levels utilising EVAR SBT, and b) investigate the impact of supervised SBT on trainee performance.

Methods: EVAR procedure-related metrics were benchmarked by 6 experienced consultants using a Simbionix Angiomentor EVAR-simulator. Sixteen vascular surgical trainees performing a comparable EVAR before and after structured simulation based training (SBT) (>4 teaching sessions) were assessed utilising a modified Likert-scale score. These were benchmarked for comparison against the standard set by the consultant body.

Results: Median procedural-time for consultants was 43.5 minutes (IQR: 7.5). A significant improvement in trainee procedural-time following SBT was observed [median procedural time
77 minutes (IQR: 20.75) vs. 56 minutes (IQR: 7.00) (p<0.0001)]. The mean [standard deviation (SD)] trainee Likert score pre- and post-SBT improved [16.6 (SD: 1.455) vs. 28.63 (SD: 2.986) (p<0.0001)]. Fewer endoleaks were observed (p=0.0063) and trainees chose an appropriately-sized device more frequently following SBT.

**Conclusion:** This study suggests that EVAR-SBT should be considered as an adjunct to standard psychomotor skill teaching techniques for EVAR within the vascular surgery training curricula.

**Keywords:** Endovascular, Simulation, Aneurysm

**INTRODUCTION**

Abdominal Aortic Aneurysm (AAA) remains an important cause of cardiovascular death(1): AAA prevalence is estimated to be between 1.25% and 4% in Western societies(2, 3). Surgical management of AAA consists of the traditional open aneurysm repair (OAR), or the more recently developed endovascular aneurysm repair (EVAR). EVAR has a lower 30-day operative mortality than OAR(4-7). However, EVAR may be associated with complications such as migration of the device or endoleak and over the long term it has a higher rate of secondary intervention (7, 8). To avoid such complications, meticulous pre-procedural planning and technical expertise are necessary. The required psychomotor skillset is different to traditional open surgery and this is compounded by increasingly frequent updates to current EVAR technologies and the availability of an ever diverse number of EVAR devices. It is therefore evident that trainees and senior surgeons need to acquire a high level of EVAR-related competency and maintain their skillset up to date in order to achieve optimal outcomes.
The reduction in training hours for doctors to comply with recent regulations in combination with changes to operating practices, e.g. traditional invasive diagnostic angiography has been replaced by non-invasive imaging techniques, have had a detrimental impact on training opportunities for core endovascular skills (9). Simulation is an attractive alternative to traditional training methods. Virtual reality (VR) simulation has shown promising results in other surgical fields, notably laparoscopic surgery (10). Within vascular surgery, VR simulation is increasingly being promoted as a means of endovascular psychomotor skill acquisition (11, 12). However, there is currently no high quality evidence regarding the use of simulators and simulator-based training (SBT) in EVAR.

The aim of this study is to assess the role of SBT using a high-fidelity VR simulator. More specifically, we aim to benchmark performance levels by assessing a series of experienced operators (consultants) and subsequently investigate the role of supervised SBT on trainee performance.

MATERIALS AND METHODS

Study group

Consultant radiologists and vascular surgeons and trainees (holders of a National Training Number and currently in a recognised training post) with an interest in endovascular surgery where approached during 4 consecutive Deanery vascular surgery training days in order to participate in the study (February 2014 to March 2015). A group of 16 vascular surgical trainees (of varying level and experience), 4 consultant vascular surgeons and 2 consultant interventional radiologists from 2 separate training regions agreed to participate (West and East Midlands). Demographic and training-related data for all trainees and consultants were recorded at baseline. Informed consent was obtained prior to participation in the study. All
consultants had previously performed at least 50 infrarenal EVAR procedures independently and were familiar with both planning and performing (independently) EVAR. Trainees without a declared interest in vascular surgery were excluded.

**Simulator**

A Simbionix Angiomentor ® (3D Systems Healthcare, Golden, CO, USA) EVAR-simulator was used (Figure 1). The device incorporates virtual reality simulation and has 10 different inbuilt EVAR modules for training and assessment. It automatically records the following parameters during the procedure: time, amount of contrast medium used, contact of wire(s) and catheter(s) with vessel wall, presence of endoleak and endoleak-related details, choice of device(s) during the procedure as well as patient-related data (heart rate, blood pressure, electrocardiogram, medication given during the procedure). Further details about the simulator have been published elsewhere and the device has been validated in a variety of endovascular settings across a number of institutions (13, 14). Data were electronically recorded and stored during the procedure in all cases.

**Simulation**

As a first step, the consultant group, after supervised familiarisation with the device (all consultants had used the simulator at least once before), performed a routine non-ruptured infrarenal EVAR and data were recorded. In the trainee cohort, comparable EVARs were carried out. Trainees were asked to perform the same EVAR procedure as the consultants, after a brief familiarisation (verbal familiarisation with the software and controls) with the simulator and prior to receiving any simulation based training (SBT). The trainees were then given 4 supervised SBT sessions over a period of 3 months, again performing non-ruptured elective infrarenal EVARs. These sessions consisted of supervised, by a consultant surgeon or
radiologist, planning and deployment of an EVAR device using the same simulator. Feedback was given to the trainees during and after EVAR. A 1:1 trainee to trainer ratio was employed. Following these sessions, the trainees carried out the same EVAR procedure that was performed at baseline and their performance was again recorded. The same generic device was used in all cases, a generic device used by the Angiomentor VR simulator. Trainees were asked to choose the appropriate device based on pre-operative and intra-operative measurements. Alongside the metrics collected by the simulator, a modified Likert scale score was recorded for the trainees, which has previously been used in similar studies (Table 1) (11). The Likert scale was completed by two independent assessors (consultants) whilst the trainee was performing the procedure; the assessors did not interact with the trainee.

Statistical Analysis
Analyses were performed using GraphPad (GraphPad Software, Inc., CA, USA). Continuous parametric data are presented as mean value ± standard deviation (SD), non-parametric data are presented as median value and interquartile range (IQR), and categorical data are presented as absolute values. Normality of distribution was assessed using skewness and kurtosis as well as the Kolmogorov-Smirnov test. Comparisons were performed using the independent or paired (where applicable) samples t-test for continuous parametric variables and Wilcoxon test for non-parametric variable, and Pearson’s chi-square test for categorical variables. A p-value level <0.05 was considered statistically significant.

RESULTS
A total of 16 trainees (all in vascular surgery) were included: 4 at specialty training (ST) level 3, 8 at ST level 4 and 4 at ST level 5. Two (12.5%) were female; all trainees had at least 12 months of experience in vascular surgery at registrar-level. All consultants had been practicing
for at least 2 years at consultant level and were performing EVARs independently (both planning and performing). The median time taken to carry out the EVAR procedure by the consultant (expert) cohort was 43.5 minutes (IQR=7.5). In the trainee cohort before SBT, the median time taken was 77 minutes (IQR=20.75). All consultants chose devices of appropriate size and there were no endoleaks on the completion angiograms. Table 2 summarizes the performance of the trainees before and after SBT. There was a significant improvement regarding duration of EVAR performed by the trainees from 77 to 56 minutes (IQR=7, p<0.0001) following supervised SBT. The mean Likert scale scores also improved significantly (p<0.0001) from a pre-SBT mean score of 16.6 (SD=1.46) to a post-SBT mean score of 28.63 (SD=2.986). Also, there were less type 1 endoleaks post–SBT (p=0.0063) and an intra-arterial catheter was advanced fewer times without a wire (p=0.002). Finally, trainees were more likely to choose a device of appropriate size (50% vs. 12.5% after training, p=0.0063).

DISCUSSION

This study aimed to investigate the role of supervised SBT in EVAR. The results of this study provide evidence that SBT in an endovascular setting significantly improves trainee EVAR planning and performance. Recent changes in surgical training in Europe and elsewhere, such as the European Working Time Directive (EWTD), have had a significant effect on training pathways, with trainees being exposed to less procedures (15, 16). Further to this, there has recently been a change in culture with consultant-led operating being standard practice. In the UK this may be related to the introduction of publically available surgeon outcome reporting; this has already impacted on the quality of training and breadth of experience in certain surgical specialties (17). In vascular surgery and interventional radiology, the impact of these constraints on training is amplified
by the fairly recent introduction of minimally invasive endovascular technologies. The latter means that the diverse collection of skills vascular surgical trainees are required to achieve competency in has increased exponentially, whereas the timeframe to achieve competency is becoming increasingly narrow. To overcome these challenges, additional strategies of psychomotor skill acquisition are needed. Further to reduced training experience, endovascular training also faces the challenge of advancing technology. An increasing number of new endovascular devices are constantly being introduced, requiring operators to be up to date with a wide variety of different pieces of equipment of increasing complexity and cost.

Endovascular skills training mirrors some of the problems experienced in the field of laparoscopic surgery, where simulation has long now been established as part of training (18, 19). Gallagher et al (20) reported that novice laparoscopic surgeons demonstrated significant improvement in incision accuracy following an initial period of training on the minimally invasive surgery trainer-virtual reality system (MIST-VR). Grantcharov et al (21) reported surgeons who were previously exposed to the MIST-VR system performed laparoscopic cholecystectomy significantly faster than those not exposed to VR training. Furthermore those with prior VR training made fewer errors and showed better economy of movement. Numerous other series have reported beneficial effects of VR training in laparoscopic surgery and it is now generally accepted that VR training is a validated training tool for a wide variety of laparoscopic procedures(22).

Endovascular interventions, similar to laparoscopy, rely on remotely accessing an area using devices introduced through easily accessible vessels and visualisation of the area of interest is achieved through angiographic imagining. Hence, it appears logical to use simulation methods similar to laparoscopic surgery in endovascular training. However, the exact role of simulation in the acquisition of endovascular skills in aneurysm repair has not previously been investigated.
Computer based VR simulation is now available in EVAR. The several endovascular VR
trainers (simulators) which are currently available commercially combine patient models with
VR to reproduce an accurate endovascular procedure simulation. Modified instruments are
inserted into haptic interface devices that recreate the sense of tactile feedback an operator
would normally experience during the procedure. Simulated fluoroscopic images are projected
onto monitors and adapt according to the instrument movements of the trainee. Simulator
patient physiological responses to the procedure and subsequent drug therapy can also be
reproduced. However, although these VR simulators provide a highly realistic environment
there are disadvantages. These are predominantly financial with cost ranging from £50,000 to
£185,000. Maintenance, housing and staffing costs also need to be taken into account. In order
for VR to be accepted as a valid endovascular training method one must demonstrate trainees
are able to improve their psychomotor skills with practice and that these improvements are
transferable to the real-life situation.

Dawson et al (12) analysed the performance of 9 surgical trainees during a 2-day endovascular
skills workshop that incorporated VR simulation. Procedural skills, including psychomotor
skills and knowledge, were assessed on a standardised iliac intervention case. Significant
improvements were demonstrated in all areas. A study by Kendrick et al (11) (12 trainees)
showed that thoracic aneurysm repair rehearsal on an endovascular simulator can reduce
procedure and fluoroscopy time, independent of trainee skill level or experience, as well as
improve subjective measures of technical success. To the best of our knowledge, there is no
literature assessing EVAR-specific VR simulation. However, a group of investigators, the
European Virtual reality Endovascular RESEARCH Team (EVEREST), have recently published
exhaustive information on the availability and possible applications of VR simulation in
endovascular procedures(23). This group has performed some pilot work in EVAR and carotid
stenting, showing that it may indeed improve outcomes(24, 25).
Our data suggest that VR simulation in EVAR improves trainee performance. However, evidence of skill transferability between the virtual and live patient is definitely a requirement before it can be fully validated as a training tool. Chaer et al (26) performed a randomised controlled trial investigating the impact of training with a virtual simulation system on subsequent performance of lower limb endovascular interventions by novice endovascular surgeons. Those surgeons randomised to the simulator group scored significantly higher than the control group in both endovascular psychomotor skills and procedural knowledge. However a major criticism was that the method of scoring was highly subjective and that overall patient outcomes were not different between the two cohorts.

Availability of VR simulators currently is not optimal across training programmes. A recent survey in the UK (performed by UK Endovascular Trainees – www.ukets.org), disclosed that 74% of surgical trainees had never used an endovascular simulator before. Based on our findings, this may impact on the quality of training provided and may have serious implications upon patient safety in the future.

Limitations

The main limitation of this study is the number of participants. This is due to constraints in terms of time and cost as well as the limited number of vascular trainees available. Additionally, in between the initial and final assessment, the trainees may have improved due to more exposure to EVAR in “real-world” environment rather than just SBT. However, the results were of important significance and potentially helpful clinical improvements were demonstrated. Furthermore, an association with improvement of real-world skills cannot been shown using our data. This requires a different study design with longitudinal real world assessments in the operating theatre.
Conclusion

Virtual reality simulation training appears to improve trainee performance in EVAR; VR SBT may subsequently be an important tool in training future surgeons and should be easily available in vascular training programmes. Research assessing translation of these findings into real world clinical practice is also required, in order to understand how to best implement simulation as part of vascular surgical training.

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REFERENCES


Figure legends

**Figure 1:** The Angio Mentor simulator used in this study