The Utility of Endovascular Simulation to Improve Technical Performance and Stimulate Continued Interest of Preclinical Medical Students in Vascular Surgery

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Objective

New training paradigms in vascular surgery allow for early specialization out of medical school. Surgical simulation has emerged as an educational tool for trainees to practice procedures in a controlled environment allowing interested medical students to perform procedures without compromising patient safety. The purpose of this study is to assess the ability of a simulation-based curriculum to improve the technical performance and interest level of medical students in vascular surgery.

Design

Prospective observational cohort study of medical student performance.

Setting

Academic medical center.

Participants

Forty-one medical students (23 first year, 15 second year, 3 other) enrolled in a vascular surgery elective course. Students completed a survey of their interests and performed a renal stent procedure on an endovascular simulator (pretest). The curriculum consisted of didactic teaching and weekly mentored simulator sessions and concluded with a final renal stent procedure on the simulator (posttest). Objective procedural measures were determined during the pre- and posttest by the simulator, and subjective performance was graded by expert observers utilizing a structured global assessment scale. After the course, the students were surveyed as to their opinions about vascular surgery as a career option. Finally, 1 year after the course, all students were again surveyed to determine continued interest in vascular surgery.

Results

The objective and subjective criteria measured on the simulator and structured global assessment scale significantly improved from pre- to posttest in terms of performer technical skill, patient safety measures, and structured global assessments. Before beginning the course, 8.5% of the students expressed high interest in vascular surgery, and after completing the course 70% were seriously considering vascular surgery as a career option ($p = 0.0001$). More than 95% of the students responded that endovascular simulation increased their knowledge and interest in vascular surgery. In the 1-year follow-up survey ($n = 23$ medical students), 35% had already entered their clinical years. Seventy percent of the students were still considering vascular surgery, while several other career options were still popular including the surgical subspecialties (70%), interventional cardiology (57%), and interventional radiology (48%). Most respondents indicated the major reasons for continued interest in vascular surgery were the ability to practice endovascular procedures on the simulator (100%) and mentorship from vascular surgery faculty (78%).

Conclusions

The use of high fidelity endovascular simulation within an introductory vascular surgery course improves medical student performance with respect to technical skill, patient safety parameters, and global performance assessment. Mentored exposure to endovascular procedures on the simulator positively impacts long term medical student attitudes towards vascular surgery. Simulator-based courses may have the potential to be

an important component in the assessment and recruitment of medical students for future surgical training programs.

Key Words: endovascular skills; integrated vascular surgery residency; medical student education; surgical simulation

Competency: Patient care; Medical knowledge; Practice-Based Learning and Improvement; Systems-Based Practice

Article Outline

Introduction

Surgical simulation has emerged as an educational tool for trainees and students to practice and rehearse procedures in a safe, controlled, risk-free setting.[1] Prospective, randomized double-blind studies have shown that subjects receiving simulation-based training demonstrate superior intraoperative performance of complex surgical skills.[2], [3] and [4] Over the past 10 years, surgical simulators have been developed for a variety of minimally invasive procedures, including laparoscopy, urology, and obstetrics/gynecology.[1] It has been suggested that simulation-based skills training should become standard in surgical residency curricula.[3] Recent changes to general surgical residency programs include the requirement by the ACGME to develop surgical skills laboratories as part of the educational curriculum.

Before simulation-based training can become widely incorporated into surgical residency programs and supplant many traditional didactic educational efforts, its effectiveness must be validated. With increasing difficulties placed on program directors because of resident work hour restrictions, as well as faculty reimbursement, much effort has been placed on new educational paradigms in surgery. Medical students provide an eager group of learners that can benefit from the recent emphasis on surgical education and simulation exposure. The development of new training paradigms in subspecialty programs such as vascular surgery has also created a need for an increasing supply of interested students to fuel the development of future programs. In 2005, the American

Board of Medical Specialists allowed for a primary certificate in vascular surgery, enabling the development of new integrated (0-5) or early specialization (4 + 2) programs leading to certification in vascular surgery.[5]

Integrated vascular residency programs will allow trainees to reduce the total training time and focus earlier on the treatment of patients with vascular diseases. This educational paradigm is geared toward medical students who have decided early to commit to the field of vascular surgery. With the development of high fidelity simulation in the field of endovascular surgery, these simulators may also be used as an educational tool for novice medical students. This early exposure can provide first and second year medical students an opportunity to learn about vascular disease and perform interventional procedures in a completely safe environment. We developed a novel endovascular skills course for preclinical medical students interested in the treatment of vascular diseases as part of the educational effort to develop our own 0-5 integrated residency programs. The purpose of this study was to assess the ability of a simulation-based curriculum to improve the technical performance and continued interest level of preclinical medical students in vascular surgery.

Methods

Study Design

This study was designed to validate the use of simulators in improving interventional skills and generating interest in vascular disease in medical students without prior exposure to the field of endovascular surgery. Following approval by the Stanford Human Subjects Review Board, 41 medical students were enrolled in a simulation-based vascular surgery elective course. The course was advertised in the online course directory, and by personal e-mail from the course director to each preclinical medical student. A survey was administered to determine the demographics, interest level, and previous experiences which may be relevant to the students' ability to learn interventional skills.

Prior to any instruction, the students received a standardized introduction to the endovascular simulator and performed a renal stent procedure (pretest). The 8-week curriculum consisted of didactic teaching in the form of reading material and weekly 30-

minute lectures covering basic catheter-based interventions, aortoiliac disease, superficial femoral artery disease, renal artery disease, and cerebrovascular disease (Fig. 1). Instruction was also provided on arteriography, guide wire manipulation, catheter exchange, and angioplasty and stenting. Each week, the students received 90-minute mentored simulator sessions and practiced carotid, renal, iliac, and superficial femoral artery interventions. Students were given the opportunity each week to be the primary operator of the procedure with direct instruction, and over the course of the study there was a standard number of sessions each student completed. The course concluded with a final renal stent procedure on the simulator (posttest) and a second survey regarding their attitudes about the curriculum.

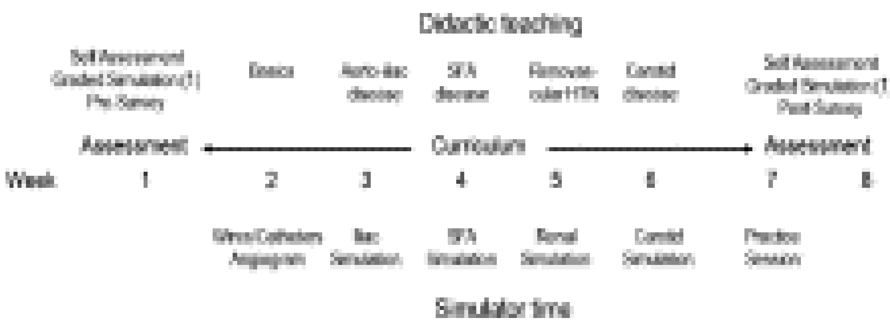

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FIGURE 1. Endovascular simulation-based curriculum used for medical student teaching class. Note the didactic topics covered weekly are immediately supplemented by active practice on the high fidelity simulator. *SFA*, superficial femoral artery; *HTN*, hypertension.

Endovascular Simulator

The Simbionix Angiomentor™ (Simbionix, Ltd., Cleveland, OH) is a high fidelity endovascular simulator which allows users to perform interventional procedures to treat carotid, renal, aortoiliac, and peripheral artery disease (Fig. 2). The system consists of a standard desktop personal computer with software which models the human arterial system in 3 dimensions. This computer is connected to a haptic module which utilizes a force feedback system to detect external devices. The user can insert standard angiographic catheters and guide wires, inject contrast dye, perform angioplasty, deploy stents, and perform fluoroscopy with digital subtraction angiography. A touch screen monitor displays the devices to be selected for simulation, and a second monitor displays a simulated fluoroscopic image. The ANGIO Mentor System is located at the Goodman Simulation Center at the Stanford University School of Medicine. This facility is accredited by the American College of Surgeons as a Level I Educational Institute.

Full-size image (21K)

FIGURE 2. Simbionix Angiomentor™ (Simbionix, Ltd., Cleveland, OH) high-fidelity endovascular simulator used in the Surgery 228 course to instruct preclinical medical students on basics of endovascular skills acquisition.

Subject Evaluation

During the pre- and posttest simulator assessments, the students were instructed to verbalize their rationale and received minimal guidance from the expert observer (attending vascular surgeon) while their technical skills were evaluated. Objective procedural measures were determined and reported by the simulator, and subjective performance was graded by several expert observers utilizing a structured global assessment scale previously validated (Fig. 3).[6] The team of expert observers have extensive experience in live and simulated endovascular procedures and as well as in the assessment of students, residents, fellows, and other practicing surgeons.

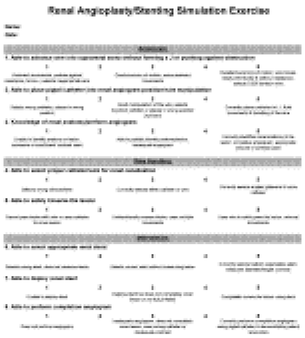
Renal Angioplasty/Stenting Simulation Exercise

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FIGURE 3. Global assessment score sheet used for grading medical students during pre- and postcourse simulator case observation.

The metrics measured by the simulator for technical skill and patient safety included total procedure time, time to the diagnostic angiogram, time to the stent deployment, percent residual stenosis, percent of lesion covered by the stent, placement accuracy, fluoroscopy time, volume of contrast injected, and the activated clotting time.

The expert observers evaluated the students' performance using an 8 question global assessment scale. Our scale was modified from those used in other endovascular simulation studies,[4] which were based on previously validated scales by Reznick et al. consisting of 7 categories to assess operative skills.[7] Our modified scale evaluated each student on 3 major tasks (angiography setup, target vessel catheterization, and intervention). Within each task, the observer used a traditional Likert scale score of 1 = fail, 2 = poor, 3 = satisfactory, 4 = good, and 5 = superior. Examples of criteria that would receive a failing score include frequently stopping the procedure to ask for help, inappropriate movements that would risk injury to the target vessel, and choosing interventional devices which may lead to vessel rupture. Examples of criteria that would receive a superior score include handling the wires and catheters in a manner which minimizes vessel damage, understanding the steps of the procedure and performing them effortlessly, and selecting appropriately sized interventional devices for the target vessel.

Statistical analyses were performed using Excel 2007 (Microsoft Corp., Redmond, WA). Two-tailed *t*-test were used to determine differences between the students before and after receiving the simulation-based curriculum. Values of $p < 0.05$ were considered significant.

Results

This study reports on 41 medical students that enrolled in this elective course. There were 23 in their first year, 15 in their second year, and 3 others (MD-PhD and undergraduate). There were 30 males and 11 females, with a mean age of 23.5 years (range, 20-29). Reasons cited in the survey data for signing up for the class included some interest in vascular surgery (74% of students), interest in surgery/surgical specialties (83%), interest in endovascular interventions (83%), interest in cardiovascular disease (85%), and interest in simulation (78%).

Performance by the students during the course was assessed as described in the methods section. Table 1 highlights the metrics determined by the high fidelity simulator for the students on their pretest versus their posttest. Significant performance improvements from pre- to posttest were seen in terms of technical skill and patient safety measures. Students were able to complete the renal stent procedure in a shorter amount of time, were quicker to perform a diagnostic aortogram, were quicker to deploy the intended renal stent, had less residual stenosis of the lesion after stenting, and more accurately deployed the stent at the center of the lesion. The students performed the procedure more safely when comparing their pretest with their posttest. Total fluoroscopy time decreased, and the activated clotting time at the time of stent deployment increased from 188 to 350 seconds, indicating the proper initiation of anticoagulation. The total volume of contrast used during the simulated case was not different from pretest to posttest. When stratified by year in medical school, there was no group difference between the groups based on previous experience, yet each group still showed similar improvements from pre- to posttest.

TABLE 1.

Simulator-Generated Objective Performance Criteria For the Entire Cohort of Students

n = 41 Medical Students	Pretest Mean	Posttest Mean	p Value
Procedure time (min)	21 : 21	14 : 32	< 0.01
Time to aortogram (min)	9 : 19	3 : 04	< 0.01
Time to intervention (min)	14 : 58	9.00	< 0.01

n = 41 Medical Students	Pretest Mean	Posttest Mean	p Value
Residual stenosis (%)	32.25	17.24	< 0.01
Lesion covered (%)	79.15	89.10	0.01
Placement accuracy (mm)	5.18%	5.71%	0.19
Fluoroscopy time (min)	11 : 02	8 : 28	< 0.01
Contrast injected (ml)	29.44	31.76	0.28
Activated clotting time at intervention (sec)	188	350	< 0.01

Subjective analysis of the students' performance determined by the structured global assessment scale also showed significant improvement on the posttest as compared with the pretest (Fig. 4). All 41 students performed at a higher global level as graded by expert observers. Analyzing the entire cohort revealed mean total score on the structured global assessment scale to be 1.82 on the pretest, which improved to 3.93 (out of maximum score of 5.0) after finishing the 8-week curriculum. Table 2 highlights the relative contribution of each of the major steps of the entire renal stent procedure, and shows significant improvement in each component for the entire group from pretest to posttest.

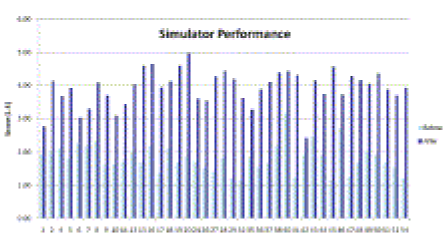

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FIGURE 4. Performance of all 41 medical students enrolled in course from 2007 to 2008 demonstrating significant overall graded performance improvement from mean of 1.82 to 3.93 ($p < 0.01$).

TABLE 2.

Structured Global Assessment Scale Scores During Simulator-Graded Sessions for Entire Cohort of Medical Students

n = 41 Medical Students	Pretest Mean	Posttest Mean	p Value
Total score	1.82	3.93	< 0.01
Angiogram score	1.80	4.04	< 0.01
Wire access score	1.88	3.90	< 0.01
Intervention score	1.77	3.83	< 0.01

Thirty-six out of 41 students (88%) completed the pre and post-survey. There was a significant increase in the students' interest level in the field of vascular disease and support of surgical simulation as an educational tool. Prior to beginning the course, 56% of the students reported being very interested in a procedure-based specialty and 8% reported being very interested (choosing 5 on a scale of 1-5) when asked about a career in vascular surgery specifically. After completing the simulation-based vascular surgery course, the percentage of students who became very interested in a procedure-based specialty rose to 72%, with 70% of the students reporting a high interest in vascular surgery ($p < 0.01$). Nearly 90% of the students agreed or strongly agreed that endovascular simulation increased their interest in additional training in vascular disease, and 94% reported that endovascular simulation increased their knowledge and interest in vascular surgery. After completing the course, 100% of students agreed or strongly agreed with the statement that residents and attending physicians in procedure-based specialties should have early experience with simulators, compared with 69% before beginning the course.

The long term follow-up survey was completed by 23 of the enrolled students (56%) 1 year after completing the course. Students were asked about the aspects of the course that were important to their educational goals. They felt the course was particularly useful in providing the opportunity to practice endovascular procedures on the simulator (100%), testing on the endovascular simulator (96%), mentorship by a vascular surgeon (78%), preparing presentations about vascular disease (57%), and having the opportunity to meet surgical residents (53%). Seventy percent of students were still interested in vascular surgery 1 year after taking the course, and several other disciplines were also popular including surgical subspecialties (70%), interventional cardiology (57%), and interventional radiology (48%). Students revealed which factors most importantly cultivated their interest in their surgical specialty of interest to be faculty mentors (87%), residents (74%), clerkships (61%), research (57%), extracurricular activities (43%), reading scientific articles, (39%), and classes (31%).

At the time of the follow-up survey, 5 students had rotated on the vascular surgery service. All 5 students reported that their participation in the course as a preclinical student enhanced their experience on the rotation. Their reasons included that they were more knowledgeable about vascular diseases and interventions (80%), they were better able to assist in the operating room (80%), and they were better acquainted with the residents and attending physicians and felt more like a member of the team (40%).

Discussion

In this study a significant improvement in the technical skill and interest level of medical students in vascular surgery was demonstrated upon completion of an 8-week standardized simulation-based course taught by vascular faculty mentors. The simulation-based endovascular curriculum combined with didactic teaching resulted in improved medical student performance on the simulator with respect to several objective metrics of technical skill and patient safety determined by the simulator. In addition, all 3 components of a previously validated global assessment scale score determined by expert observers were considerably improved in this very novice group.

An often overlooked group of eager and effective learners among surgery program directors are medical students, particularly in their preclinical years. With the development of many new residencies, particularly in the surgical subspecialties, earlier exposure can create long-lasting impressions and opportunities to become interested in the field. Certainly, in this cohort of students, simulators can offer previously unavailable exposure to hands-on procedural techniques and complex clinical scenarios.[8] This early experience might be particularly crucial for medical students interested in surgical subspecialties that have early specialization integrated training programs. Previous reports have shown residents in integrated plastic surgery residency programs had better quantitative educational metrics during medical school than their counterparts in independent plastic surgery programs.[9] To be a competitive applicant for an integrated subspecialty surgical residency program, a medical student likely needs to develop an early interest in the field, often times by clinical rotations, preclinical courses, or research involvement. In a preliminary comparison, at our institution, of applicants to an integrated vascular surgery residency versus traditional general surgery residency we found a much higher percentage identifying a vascular surgeon as a mentor (91% vs. 45%).

In an older survey from 2006, 90 vascular surgery fellows in the traditional 5-2 track revealed that only 16% of them decided on vascular surgery as a potential career option during medical school, whereas the remaining 84% committed to vascular surgery during their general surgery residency training.[10] For the new 0-5 integrated programs to be successful in the long term, medical students must develop an early and lasting interest in vascular surgery. While many medical schools offer clinical clerkships and electives in vascular surgery for third and fourth year students, very few offer any experiences in vascular surgery for first and second year students. Using a simulator-based curriculum, the students participating in this course and this study had an in-depth opportunity to learn about minimally invasive vascular interventions.

With the paradigm shift in treatment of vascular diseases to a less invasive approach, simulators have served multiple purposes for vascular surgery educators. Vascular surgeons have embraced the endoluminal techniques in the treatment of aortoiliac, cerebrovascular, and peripheral vascular diseases. As a result, vascular surgery trainees at all levels have to develop catheter-based endovascular skills, a requirement that helped fuel the development of endovascular simulators, particularly for credentialing issues. Endovascular interventions are well suited for simulation because they require the trainee to manipulate wires and catheters in 3 dimensions while viewing a 2-dimensional fluoroscopic image.[11] Studies have demonstrated that surgeons with minimal endovascular experience can improve their technical performance after short-phase training on an endovascular simulator.[12]

Besides the obvious risk-free environment to practice procedures for eager novice medical students, much can be learned about the development of surgical skills, which is of interest to all surgical educators. Measuring proficiency during surgical training in its current form carries many known challenges, and some have suggested the use of an objectified subjective global assessment scale, such as the Objective Structured Assessment of Technical Skills (OSATS), to more accurately measure trainee skill and progress over time.[7] The scale used in this study was based on this format and has been validated in a prior study to reliably distinguish between individuals with varying procedural experience.[5]

While it is clear that practicing procedures on the simulator improved the students' technical skills, our study did not discern whether it was the high fidelity simulator or the mentorship by a faculty vascular surgeon that played the most important role in stimulating the medical students' interest in vascular surgery. This poses 1 of the limitations of this study. While early simulator experience may influence preclinical medical students' clinical interests, other factors such as research, clerkships, and mentors will also ultimately play a role in their decision to pursue a certain specialty. Another potential future study involves the long term benefit of such early exposure to endovascular simulation. Although the students' skill and interest level rose significantly after completing the simulation-based course, further studies involving repeated assessments will be necessary to determine whether these early positive results are sustained over time. Another intriguing future question will be the amount of time necessary in practice for each student to attain an acceptable level of proficiency. With the current interest in proficiency-based curriculums, simulation metric analysis can be important to help guide learning of technical procedures.

Still, we feel the novice medical students with no prior experience in vascular diseases or endovascular interventions can be very efficiently and safely taught about complicated vascular interventions through a simulation-based curriculum. We have found that such a course increased their knowledge and interest level in vascular disease. This translates into long term interest in pursuing additional vascular training or a career in a catheter-based specialty, and certainly supports simulation as an educational and recruitment tool.

In summary, the use of high fidelity endovascular simulation within an introductory vascular surgery course improves medical student performance with respect to technical skill, patient safety parameters, and global performance assessment. Mentored exposure to endovascular procedures on the simulator positively impacts long term medical student attitudes toward vascular surgery. Simulator-based courses may have the potential to be an important component in the assessment and recruitment of medical students for future surgical training programs.

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