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Should simulator-based endovascular training be integrated into general surgery residency programs?

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Abstract

Background: The impact of high-fidelity simulators as an adjunct for endovascular training of general surgery residents has not yet been defined. The purpose of this study was to evaluate general surgery resident perspectives on the value of a simulator-based endovascular training program by using various measurement tools.
Methods: General surgery residents in postgraduate years 1 to 5 (n = 50) participated in a focused endovascular training course covering aortoiliac, renal, and carotid artery disease. The components of the course included didactic lecture, self-learning course material and computer training modules, hands-on exposure to endovascular instruments, and endovascular procedure simulation using a mobile SimSuite unit (Medical Simulation Corporation, Denver, CO). Course participants completed pre- and postcourse questionnaires, knowledge-based testing, and endovascular simulator metric testing.
Results: Of the 50 general surgery residents who completed the precourse questionnaire and knowledge-based testing, 41 completed the entire program including the postcourse questionnaire and knowledge-based testing, and 33 completed endovascular simulation metric testing. Subjective responses from pre- and postcourse surveys highlighting the residents' perceptions of the potential role of endovascular simulation as part of general surgery residency training showed favorable responses. On completion of the course, mean knowledge-based test scores had statistically significant improvement (pretest, n = 50, 59.5% ± 12.1% correct and posttest, n = 41, 69.1% ± 15.4% correct [P = .003]). For metric testing of a simulated endovascular procedure (n = 33), 93.9% completed all of the defined tasks within the allotted time period (mean time, 12.2 ± 4.36 minutes; range, 4.1–26.6 minutes; 95% confidence interval for mean 10.8–13.6 minutes).
Conclusions: Based on subjective and objective measures, general surgery residents found valuable and benefited in knowledge base from a focused simulator-based endovascular training program. Integrating endovascular simulation into general surgery resident training and its influence on resident interest in vascular specialization as a career choice holds future potential.

Keywords: Endovascular simulation; Surgical resident education

Traditional resident educational paradigms are shifting as a result of changes in health care over the past decade. With shorter hospital inpatient length of stay, more emphasis on outpatient care, mandated restrictions on resident work hours, increased minimally invasive technologies, and increased attention on quality of care and patient safety by reducing medical errors, general surgery residents have the potential for less contact with patients and reduced procedural experience during residency, the net effect of which has yet to be realized [1].

Concurrent with these trends and their impact on resident training is a redefining of how vascular surgeons will be trained. With the Accreditation Council for Graduate Medical Education approval of the Primary Certificate in Vas-

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cular Surgery in February 2006 is the potential for different pathways for vascular surgical specialization, including the opportunity for decision as early as medical school. With the goal of earlier specialization to improve recruitment into vascular surgery, the dilemma exists in how to increase interest and exposure to the field at a time when traditional educational paradigms are shifting.

As these resident training issues have been evolving, there has also been a parallel expansion of educational technology, especially in the area of surgical simulation. Although the use of simulation is well established in other industries such as aviation and aeronautics, its comparable use in surgery is still in evolution. Simulation has been used in some surgical fields with success [2–9], and, more recently, the use of high-fidelity endovascular simulation has also been reported [10–13]. However, the role of endovascular simulators as an adjunct for endovascular training of general surgery residents has not yet been defined. The purpose of this study was to evaluate the potential impact of a focused simulator-based endovascular program on general surgery resident training perspectives using various measurement tools as a precursor toward establishing endovascular simulation as a fixed part of a general surgery resident training curriculum.

Methods

General surgery residents in postgraduate years (PGYs) 1 to 5 and research (between PGY 3 and PGY 4 years) at Vanderbilt University Medical Center, Nashville, TN, participated in a comprehensive endovascular simulator-based training course. There were two 2-day courses with session 1 (December 2005) focusing on aortoiliac and renal disease and session 2 (February 2006) focusing on carotid artery occlusive disease. The components of the course included (1) didactics with group lecture, self-learning print material, and computer training modules; (2) hands-on exposure to different guidewires, catheters, balloons, and stents; and (3) endovascular procedure simulation. Course participants completed pre- and postcourse questionnaires, knowledge-based testing, and endovascular simulator metric testing.

Precourse questionnaire and knowledge-based testing

Before beginning the course (session 1), a multiple-choice precourse questionnaire was provided to each resident. Residents were asked to provide prior vascular experience based on rotation time and major index vascular case volume. Questions regarding prior endovascular experience (number of previous angiograms and angioplasty/stenting procedures), perspective regarding endovascular simulator training, and opinions concerning vascular surgery as a career were included in the survey. Precourse knowledge-based testing included (1) a fill-in-the-blank test of vascular anatomy (abdominal and pelvic) with visual cues in the form of acronyms for each named vessel provided and (2) a precourse clinical case of an endovascular procedure (iliac stenting) in which the resident needed to provide the correct chronological order for completion of the procedure. Residents were given 30 minutes to complete the precourse survey and knowledge-based testing.

Didactics

For session 1, immediately after the precourse questionnaire and knowledge-based testing, a group lecture (1 hour) was given reviewing basic vascular anatomy and physiology, indications, general endovascular techniques, and specific clinical scenarios with review of endovascular procedure sequence (aortoiliac and renal artery occlusive disease). Each resident was also provided a course manual with printed material pertinent to the course topics for independent review. For session 2, an independent computer online training module was used to provide didactics for carotid artery occlusive disease (https://live.medsn.com/carotid/). Guidelines published by the Clinical Curriculum Committee and the Association of Program Directors in Vascular Surgery, as well as evidence-based recommendations from the Society for Vascular Surgery, Society for Interventional Radiology, American Heart Association, American College of Cardiology, and other societies were emphasized in all course materials [14–25].

Endovascular simulator training

Immediately before the simulator portion of the course, hands-on exposure to different guidewires, catheters, balloons, and stents specific to each procedure (aortoiliac, renal, and carotid endovascular procedures) with instructions on use provided on an individual resident basis (30–60 minutes). Two mobile SimSuite units (Medical Simulation Corporation, Denver, CO; http://www.medsimulation.com/) housed in full-length buses were used for endovascular simulator training. SimSuite system software allowed for clinical scenarios for each endovascular-simulated procedure providing real-time patient monitoring; visual feedback of the vascular anatomy through simulated fluoroscopy; on-screen endovascular instrument selection representing simulated guidewires, catheters, balloons, and stents; and a haptic interface that allowed simulated endovascular instrument manipulation. Each resident was given a 1-hour time slot during each of the two 2-day sessions (2 hours total simulator time per resident). During session 1, residents completed simulated iliac and renal stenting procedures, and, during session 2, residents completed a simulated carotid stenting procedure. A clinical specialist from the Medical Simulation Corporation was present for technical support and clinical guidance during each simulated case.

Postcourse questionnaire and knowledge-based testing

On completing the entire course, each resident filled out a multiple-choice postcourse questionnaire. Postcourse questions and answers were designed on a 1 to 5 scale (1 = "strongly disagree," 2 = "somewhat disagree," 3 = "neutral," 4 = "somewhat agree," and 5 = "strongly agree"). Several postcourse questions overlapped with precourse questions to evaluate changes in resident perspective after endovascular simulation experience. A postcourse knowledge-based test was given with a similar format as the precourse knowledge-based test but with different content including (1) a fill-in-the-blank anatomy test of vascular anatomy (lower extremity) without vessel acronyms and (2) a postcourse clinical case of an endovascular procedure (renal stenting) in which the resident needed to provide the correct

Table 1
Precourse questionnaire: prior resident vascular surgery rotation time and operative case volume experience level (n = 50)

	PGY 1 (n = 16)	PGY 2 (n = 9)	PGY 3 (n = 4)	Research (n = 12)	PGY 4 (n = 3)	PGY 5 (n = 6)
How many months have you spent on a vascular service during your residency?	1.0 ± 1.5 (0–2)	2.0 ± 0.7 (1–3)	3.5 ± 1.0 (2–4)	3.9 ± 0.7 (3–6)	4.2 ± 0.6 (3–5)	6.5 ± 2.0 (3–8)
How many major vascular index cases have you done so far during your residency?	3.1 ± 3.9 (0–15)	9.8 ± 4.8 (0–10)	33.3 ± 5.8 (30–40)	47.3 ± 35.7 (10–100)	43.4 ± 37.1 (8–82)	82.5 ± 29.3 (25–100)

Mean ± standard deviation (range).

chronological order for completion of the procedure. Residents were given 30 minutes to complete the postcourse survey and knowledge-based testing.

Endovascular simulator metric testing

Because of time constraints, precourse metric testing had not been performed and not all residents were able to undergo postcourse metric testing, with selection randomly based on participating resident availability. After the completion of session 2, a repeat simulated iliac stent case was performed. The same case scenario performed in session 1 was used for all residents after completion of session 2 (3 months between sessions). Residents were instructed to complete the simulated case independently in a 20-minute time period. Although a clinical specialist was available to assist with software interface, no clinical guidance was provided. Required procedural steps included (1) guidewire and catheter selection with advancement into the aorta for performing a diagnostic angiogram, (2) identification of arterial anatomy and pathology, (3) guidewire and catheter selection to allow crossover catheterization of the contralateral iliac artery, (4) balloon angioplasty and/or stent deployment to treat iliac stenosis, and (5) completion angiogram. The completion of each task was confirmed by an experienced observer. The following metric data points were collected and analyzed: procedure time, contrast type, volume of contrast, fluoroscopy exposure times, type and number of wires and catheters, pre- and/or postdilation of stenosis, type and size of stent, and treatment of possible postprocedure dissection.

Statistical analysis

Pre- and postcourse questionnaire data were analyzed with descriptive statistics. Pre- and postcourse knowledge-based tests were scored, and mean and standard deviation was calculated. Metric data were analyzed by using Statistica 7.1 (StatSoft, Inc, Tulsa, OK). Comparisons of means were made by using an unpaired and paired Student t test with P values $< .05$ considered statistically significant.

Results

Of the 50 residents (PGY 1 = 16, PGY 2 = 9, PGY 3 = 4, research = 12, PGY 4 = 3, and PGY 5 = 6) completing precourse questionnaire and knowledge-based testing, 41 (PGY 1 = 11, PGY 2 = 9, PGY 3 = 4, research = 10, PGY 4 = 3, and PGY 5 = 4) completed the entire program (sessions 1 and 2) including a pre- and postcourse questionnaire and knowledge-based testing. Metric testing was performed on 33 residents (PGY 1 = 9, PGY 2 = 6, PGY 3 = 4, research = 7, PGY 4 = 3, and PGY 5 = 4).

The precourse questionnaire

Fifty residents completed the precourse questionnaire. Background data relevant to each resident's vascular surgical education and previous endovascular experience are shown in Tables 1 and 2. Although residents spend only a few months on the vascular services in the PGY 1 to 2 years, the case volume for both traditional and endovascular procedures increased more substantially later in the PGY 3 to 5/research years (mean vascular operative case volume: PGY 1–2 = 6.6 ± 4.4; PGY 3–5/research = 54.5 ± 34.8; $P = .001$). Focusing on prior endovascular experience level, most residents have performed less than 10 endovascular procedures in each index category (diagnostic angiography, iliac stenting, and renal stenting), even in the PGY 3 to 5/research years.

Resident perspective regarding the role of endovascular simulation as part of general surgery training is shown in Table 3. Although most residents (82%) acknowledged that endovascular techniques should be part of their general surgery training, only a few (2%) thought traditional meth-

Table 2
Precourse questionnaire: prior resident catheter experience based on case volume (n = 50)

	0 (%)	1–5 (%)	5–10 (%)	10–25	>25 (%)
How many diagnostic angiograms (aorta/lower extremity) have you performed?	22 (44)	18 (36)	8 (16)	1 (2)	1 (2)
How many iliac balloon angioplasty or stent procedures have you performed?	25 (50)	20 (40)	4 (8)	1 (2)	—
How many renal or visceral angiograms have you performed?	42 (84)	7 (14)	1 (2)	—	—
How many renal or visceral balloon angioplasty or stent procedure have you performed?	44 (88)	6 (12)	—	—	—

Table 3
Precourse questionnaire: the role of endovascular simulation in general surgery residency training (n = 50)

	Yes (%)	No (%)	Maybe (%)	Not sure (%)
Is there need for endovascular skills as part of your general surgery training?	42 (84)	1 (2)	6 (12)	1 (2)
Are traditional general surgery education methods adequate enough during general surgical residency training to be able to perform endovascular procedures after residency?	1 (2)	26 (52)	6 (12)	17 (34)
Have you spent training time on an endovascular simulator in the past?	—	49 (98)	—	1 (2)
Should endovascular training be added to traditional surgical training methods as part of surgical residency?	25 (50)	2 (4)	14 (28)	9 (18)
Do you think endovascular procedures should be performed in practice only after vascular fellowship?	23 (46)	9 (18)	8 (16)	10 (20)
Are you interested in vascular surgery as a career?	7 (14)	24 (48)	12 (24)	7 (14)

ods are adequate enough to meet endovascular training needs. Before participating in this course, none of the residents had any prior experience with endovascular simulation, yet 50% thought conceptually it should be included as part of their training.

The postcourse questionnaire

Forty-one residents completed the entire program (sessions 1 and 2) including both pre- and postcourse questionnaires. Table 4 shows resident perspective on the validity of the endovascular simulator experience. Overall, most residents (98% "somewhat agree" or "strongly agree") found endovascular simulation to be a useful training tool, with a favorable educational experience by participating in the course noted (91% "somewhat agree" or "strongly agree"). Regarding face and content validity, most residents found guidewire, catheter, balloon, and stent manipulations to have lifelike tactile feedback (74% "somewhat agree" or "strongly agree") and clinical case content to seem realistic (90% "somewhat agree" or "strongly agree").

Resident perspective regarding value of endovascular simulator training as part of general surgery residency curriculum is shown in Table 5. Similar to the precourse questionnaire, few residents thought traditional surgical educational methods were adequate enough (4% "somewhat agree" or "strongly agree"), but, after completing the course, more residents agreed that endovascular simulation should be part of the general surgery residency curriculum (95% "somewhat agree" or "strongly agree"). As to how to incorporate endovascular simulator training, responses were more widely distributed on whether it should be voluntary (34% "somewhat agree" or "strongly agree") or mandatory (81% "somewhat agree" or "strongly agree") and whether it should be just limited to once during the entire residency (66% "somewhat agree" or "strongly agree"), part of an annual training effort (78% "somewhat agree" or "strongly agree"), or a fixed part of vascular experience with independent access for self-learning (78% "somewhat agree" or "strongly agree"). Residents were less in favor of endovascular simulation being used for objective skills assessment (39% "somewhat agree" or "strongly agree") or used to identify residents with aptitude for vascular specialization (29% "somewhat agree" or "strongly agree"). On completion of the course, endovascular simulation had increased interest among residents in vascular surgery as a career choice (34% "somewhat agree" or "strongly agree") more so than those who were committed to vascular surgery as a career choice in the precourse questionnaire (14%).

Resident perspectives on endovascular procedure volume anticipated by the end of residency and perceived

Table 4
Postcourse questionnaire: resident perspective on endovascular simulator technology validity (n = 41)

	1 (strongly disagree) (%)	2 (somewhat disagree) (%)	3 (neutral) (%)	4 (somewhat agree) (%)	5 (strongly agree) (%)	Mean ± SD
The endovascular simulation is a useful training and educational tool	—	—	1 (2)	7 (17)	34 (81)	4.8 ± .47
Guidewire and catheter manipulation and tactile feedback are lifelike	—	2 (5)	9 (21)	27 (64)	4 (10)	3.8 ± .69
Balloon and stent manipulation and tactile feedback are lifelike	—	3 (7)	8 (19)	26 (62)	5 (12)	3.8 ± .76
The cases were sufficiently realistic to be useful for training	—	—	4 (10)	15 (36)	23 (54)	4.4 ± .67
I learned new information or skills from my participation	—	1 (2)	3 (7)	9 (21)	29 (70)	4.6 ± .74
By practicing on the simulator, my confidence and skills to perform real cases has improved	—	1 (2)	3 (7)	13 (31)	25 (60)	4.5 ± .74

SD = standard deviation.

Table 5
Postcourse questionnaire: resident perspective regarding value of endovascular simulator training as part of surgical residency curriculum (n = 41)

	1 (strongly disagree) (%)	2 (somewhat disagree) (%)	3 (neutral) (%)	4 (somewhat agree) (%)	5 (strongly agree) (%)	Mean ± SD
Traditional surgical education methods are adequate enough to perform endovascular procedures after residency	14 (34)	17 (42)	8 (20)	1 (2)	1 (2)	1.95 ± .94
Endovascular simulator training should be part of general surgery residency curriculum	0%	0%	2 (5)	21 (51)	18 (44)	4.4 ± .59
Endovascular simulator training should be a mandatory part of general surgery curriculum	0%	3 (7)	9 (22)	19 (46)	10 (25)	3.9 ± .87
Endovascular simulator training should be a voluntary part of general surgery curriculum	5 (12)	18 (44)	5 (12)	9 (22)	5 (12)	2.8 ± 1.26
Endovascular simulator training should be an annual training exercise during general surgery residency	0%	2 (5)	7 (17)	18 (44)	14 (34)	4.1 ± .85
Endovascular simulator training should be a limited training exercise at least once in general surgery residency	3 (7)	7 (17)	4 (10)	18 (44)	9 (22)	3.6 ± 1.23
Endovascular simulators should be a fixed part of general surgery training including access for independent practice	0%	2 (5)	7 (17)	16 (39)	16 (39)	4.1 ± .87
Endovascular simulators should be used for objective assessment of resident skills	2 (5)	5 (12)	18 (44)	11 (27)	5 (12)	3.3 ± 1.01
Endovascular simulators should be used to identify residents with skills and aptitude for future vascular specialization	3 (7)	14 (34)	12 (30)	7 (17)	5 (12)	2.9 ± 1.15
Participation in this course increased my interest in vascular surgery as a potential career choice	0%	8 (20)	19 (46)	11 (27)	3 (7)	3.2 ± .86

SD = standard deviation.

volume needed to achieve competency are shown in Table 6. For both diagnostic angiography (aorta/lower extremity) and balloon angioplasty/stent procedures (iliac), there is a gap in the case volume the residents think they will have performed by the end of residency and the volume they think they need to be competent (diagnostic angiography: anticipate volume >10 cases [66%] versus perceived volume needed for competency >10 cases [87%]; iliac angioplasty/stent: anticipated volume >10 cases [41%] versus perceived volume needed for competency >10 cases [82%]). If endovascular simulation was available as part of general surgery residency training, there was a shift in perceived volume needs for endovascular procedures toward fewer actual cases, but this gap persisted (diagnostic

Table 6
Postcourse questionnaire: resident perspective on endovascular procedure volume needs for both simulated and actual cases to achieve competency

	0 (%)	1–5 (%)	5–10 (%)	10–25 (%)	>25 (%)
How many diagnostic angiograms (aorta/lower extremity) do you think you will actually perform by the end of residency?	—	5 (12)	9 (22)	21 (51)	6 (15)
How many diagnostic angiograms (aorta/lower extremity) do you think you need to perform during residency in order to be competent to perform in practice?	—	1 (2)	4 (10)	12 (29)	24 (59)
If endovascular simulation was available, what is the minimal number of simulated diagnostic angiograms (aorta/lower extremity) needed to supplement live case experience?	—	2 (5)	13 (32)	19 (46)	7 (17)
If endovascular simulation was available, how many diagnostic angiograms (aorta/lower extremity) would be needed in residency in order to be competent to perform in practice?	—	1 (2)	2 (5)	20 (49)	18 (44)
How many balloon angioplasty/stents (iliac) do you think you will actually perform by the end of residency?	3 (7)	5 (12)	16 (39)	12 (29)	5 (12)
How many balloon angioplasty stents (iliac) do you think you need to perform during residency in order to be competent to perform in practice?	—	1 (2)	1 (2)	17 (41)	22 (54)
If endovascular simulation was available, what is the minimal number of simulated balloon angioplasty stents (iliac) needed to supplement live case experience?	—	2 (5)	12 (29)	17 (41)	10 (24)
If endovascular simulation was available, how many balloon angioplasty stents (iliac) would be needed in residency in order to be competent to perform in practice?	—	2 (5)	5 (12)	16 (39)	18 (44)

angiogram: perceived volume needed for competency >25 cases without endovascular simulation [59%] versus with endovascular simulation [44%]; iliac angioplasty/stent: perceived volume needed for competency >25 cases without endovascular simulation [54%] versus with endovascular simulation [44%]).

Knowledge-based testing

Forty-one residents completed both pre- and postcourse knowledge-based testing. Overall, mean knowledge-based test scores revealed statistically significant improvement on completion of the course (pretest, n = 41, 59.5% ± 12.1% correct and posttest, n = 41, 69.1% ± 15.4% correct [P = .003]). Figure 1 shows differences in percent correct between pre- and postcourse knowledge-based test scores stratified by PGY year, with most residents in all years experiencing improved test scores. Table 7 compares precourse and postcourse mean test results based on stratification by PGY year grouped by experience, with statistically significant differences noted in mean test results both between and within PGY 1 to 2 and PGY 3 to 5/research groups. Although both groups improved in knowledge-based testing measurements on completing the course, the statistical difference of postcourse test scores between PGY 1 to 2 was less than PGY 3 to 5/research group as noted in the P value trends.

Metric testing

After completing the entire program (sessions 1 and 2), 33 residents underwent a simulated endovascular case for metric testing. Thirty-one (93.9%) completed all of the defined tasks within the allotted time period (mean time, 12.2 ± 4.4 minutes; range, 4.1–26.6 minutes; 95% confidence interval for mean 10.8–13.6 minutes). The comparison of mean times between PGY 1 to 2 (n = 15) and PGY 3 to 5/research (n = 18) groups showed a statistically significant difference favoring the later group (PGY 1–2: 14.0 ± 4.9 minutes versus PGY 3–5/research group: 10.8 ± 3.5 minutes; P = .04). The total mean fluoroscopy time was 416 ± 224 seconds, and the total mean contrast volume used was 102 ± 63 mL. The overall mean number of wires used to complete the procedure was 2.0 ± 2.8, and the mean number of catheters was 3.4 ± 1.4. A dissection occurred in 64% of the simulated procedures but was treated correctly only 22% of the cases.

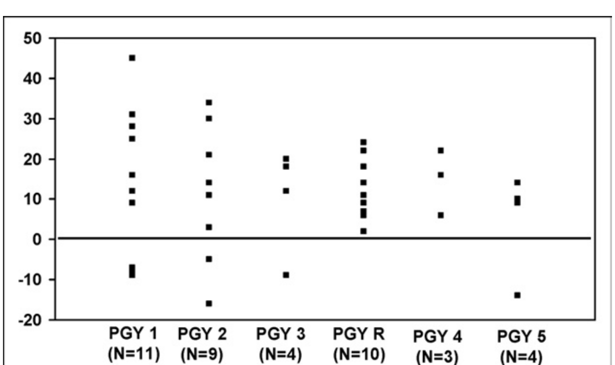

Fig. 1. Differences in percentage correct (y-axis) between pre- and postcourse knowledge-based test scores stratified by PGY (x-axis) (n = 41).

Table 7
Comparison of mean precourse and postcourse knowledge-based test scores for residents completing entire endovascular simulator course stratified based on PGY of training (n = 41)

	PGY 1–2 (n = 19)	PGY 3–5, research (n = 22)	P value*
Pre-course test	53.4 ± 11.9	63.5 ± 10.1	.008
Post-course test	64.3 ± 15.9	73.3 ± 13.3	.059
P value†	.023	.008	

* Student t test comparing precourse and postcourse test results between PGY 1–2 and PGY 3–5, research groups.

† Student's t test comparing precourse and postcourse test results within PGY 1–2 and PGY 3–5, research groups.

Comments

Should simulator-based endovascular training be integrated into general surgery residency programs? From subjective resident responses both before and after participating in a focused endovascular simulator-based training program, the straightforward answer is yes. In this study, both in pre- and postcourse questionnaires, general surgery residents clearly recognized that current traditional methods are not adequate to meet endovascular training needs (96%), with most residents agreeing that endovascular simulation should be part of the residency curriculum (95%). Although none of the residents had any endovascular simulator experience before participating in the course, most residents (98%) found endovascular simulation to be a useful training tool with a favorable experience after participating in the course noted (90%).

Although traditional methods of procedural training with direct mentoring by experienced surgeons represents an important aspect of surgical resident training and cannot be completely replaced, the use of endovascular simulation offers an important adjunct that may increase resident preparedness, improve quality of care and patient safety, and decrease the volume of actual cases needed for competency. In this study, residents acknowledged a perceived gap in their ability to acquire enough endovascular experience during general surgery residency to achieve competency based on current training models. What challenges this perceived case volume need among general surgery residents is the shift within vascular surgical practice patterns toward more catheter-based procedures, which at our institution has not been realized as much in the general surgery resident operative experience and has been focused more into the vascular fellowship training program, a trend that has been observed in other areas of operative vascular surgery [26,27]. As a result, anticipated general surgery resident endovascular operative experience falls short of that required for competency as recommended by current society guidelines [14–24]. Interestingly, only a modest portion of general surgery residents (46%) in this study thought endovascular procedures should be performed only after vascular fellowship, a perspective that may deviate from reality as suggested by higher-volume–recommended requirements for competency and as vascular surgical specialization evolves toward more catheter-based therapies [28–30].

What then becomes debatable is whether endovascular simulation can close this gap to allow for less actual case volume needed for competency both in general surgery residency and vascular fellowship [31]. To achieve this goal, there needs to be better validation of the impact of endovascular simulation. Subjectively, after participation in this course, residents found face and content validity of endovascular simulation to be adequate with guidewire, catheter, balloon, and stent manipulations having lifelike tactile feedback (74%) and clinical case content seeming realistic (90%), although this response is tempered by the variable and limited prior catheter-based experience of the study group. What has yet to be better defined for endovascular simulation is concurrent, discriminate, and predictive validity. In this study, objective traditional knowledge-based testing was used to assess the impact of a focused endovascular simulator training program that combined didactics, hand-on exposure to catheter based instruments, and endovascular case simulation. Overall, mean knowledge-based test scores revealed statistically significant improvement on completion of the course (pretest, n = 41, 59.5% ± 12.1% correct and posttest, n = 41, 69.1% ± 15.4% correct [P = .003]), with stratification based on PGY grouping showing a predictably greater improvement trend in the less experienced groups, an observation that has been shown by others [10,11]. However, because this study was not designed to test concurrent validation, it is difficult to separate whether this knowledge-based test score improvement was from the endovascular simulation portion alone or the entire educational program.

Based on the metric testing performed on completion of the course, 93.9% of residents were able to complete all of the defined endovascular tasks within the allotted time period, again with a statistical difference noted in duration of procedure based on PGY stratification. However, the metric testing performed in this study was directed at establishing baseline skill after focused exposure to endovascular simulation only and was not meant to evaluate the impact of the endovascular simulation on actual skills training. Although evaluating performance by completion of procedural steps, time to completion, or other recordable parameters offers some validation, it falls short of predictive validation. Better objective criteria are still needed to determine the actual impact of endovascular simulation on skills training [12,31]. This may explain why surveyed residents in this study were less in favor of endovascular simulation in its current form being used for objective skills assessment (39%) or used to identify residents with aptitude for vascular specialization (29%).

Although responses were more widely distributed on how to incorporate endovascular simulator training, most residents agreed that it should be mandatory (81%) and either part of an annual training program (78%) or incorporated into the vascular rotation with opportunity for independent access for self-learning (78%). For endovascular simulation to be most effective as an educational tool, there needs to be repetitive exercises beginning with early skills acquisition before advancing to higher level skills training. This study was limited by only brief access to a mobile high-fidelity endovascular simulator unit. Although the survey data provide important information regarding general surgery resident perspectives on the role of endovascular simulation for training, the ability to test skills acquisition was limited. For graduated skills training using endovascular simulation to be most effective, there needs to be a dedicated fixed unit with an established and validated training program.

Although the impact of endovascular simulation on surgical skills training continues to evolve, currently the most important aspect of offering endovascular simulation within general surgery resident training is the potential to attract interest into vascular specialization [32]. As with most general surgery residency programs, vascular operative volume for both traditional and endovascular procedures increases more substantially later in training (mean vascular operative case volume: PGY 1–2 = 6.8 ± 4.4 and PGY 3–5/research = 54.5 ± 34.8; P = .001). Although this top-heavy trend has been adequate for the traditional vascular fellowship pathway timeline that required completion of a general surgery residency before beginning vascular fellowship, now with the Primary Certificate in Vascular Surgery and the opportunity for earlier specialization, there is a critical need to improve interest and exposure to vascular surgery as a field earlier. On completion of this brief focused course, exposure to endovascular simulation had increased interest among residents in vascular surgery as a career choice (34%) more so than those who were committed to vascular surgery as a career choice in the precourse questionnaire (14%), although this difference may be from variance in the structure of the requested responses representing more of a conversion of uncertain answers from the precourse survey. Regardless, as the Association of Program Directors in Vascular Surgery forges the new training pathway and curriculum for vascular fellowship, there needs not only to be consideration for endovascular simulation among vascular fellows but also to extend these experiences into general surgery residency and medical school in an effort to improve recruitment into the specialty.

In conclusion, based on subjective and objective measures, general surgery residents found valuable and benefited in knowledge base from a focused simulator-based endovascular training program. Integrating endovascular simulation into general surgery resident training and its influence on resident interest in vascular specialization as a career choice holds future potential.

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