Motion metrics reliably differentiate competency: Fundamentals of endovascular and vascular surgery

Viony M. Belvroy, MD,[a,b] Barathwaj Murali,[c] Malachi G. Sheahan, MD,[d] Marcia K. O'Malley, PhD,[c] *and* Jean Bismuth, MD,[a] *Houston, Tex; Utrecht, The Netherlands; and New Orleans, La*

ABSTRACT

Objective: The Fundamentals of Endovascular and Vascular Surgery, a curriculum that includes an endovascular model for skills testing, aims to differentiate between competent and noncompetent performers. The aim of our study was to further validate the model and to test its reliability in assessing the performance of endovascular trainees in an uncontrolled setting.

Methods: The model was tested exclusively in a virtual reality environment. On the basis of their endovascular experience, 52 participants were divided into three groups: novice (<50 endovascular cases), intermediate (50-500 endovascular cases), and expert (>500 endovascular cases). Performance was evaluated in four tasks, measuring the tool tip position and velocity on the virtual model. Average tool tip velocity and movement smoothness in the velocity frequency domain are validated parameters defining proficiency of movement. The data were filtered and interpolated to calculate the metrics. Trials containing critical tool manipulation errors were excluded.

Results: In total, 52 tasks completed by novices, 25 completed by intermediates, and 38 completed by experts were analyzed to determine performance. The difference in performance between the novice and expert groups was statistically significant for guidewire smoothness ($P < .001$). The expert group had a statistically significantly higher average guidewire velocity compared with the novice group ($P < .001$).

Conclusions: The Fundamentals of Endovascular and Vascular Surgery model continues to differentiate novices from experts on the basis of their handling of guidewire and catheter tools, measured as smoothness and velocity. This model offers a useful instrument to test competency of endovascular surgeons. (J Vasc Surg 2020;■:1-6.)

Keywords: Endovascular aortic repair; EVAR; Educational; Abdominal aorta

In 2010, Bismuth et al[1] wrote a report about the need for uniformity of technical skills in graduating vascular surgery residents. Throughout a residency program, trainees gain skills; however, these skills are never objectively evaluated in vascular surgery residents.

As a prerequisite for certification, it is required by the American Board of Surgery that graduating residents pass the Fundamentals of Laparoscopic Surgery examination.[2] Research with Fundamentals of Laparoscopic Surgery demonstrates that with only moderate practice, significant improvement can be achieved.[3] Likewise, Fundamentals of Endoscopic Surgery has been developed to test endoscopic surgery skills.[4]

To objectify the needs for a vascular surgery educational program, Panetta et al[5] wrote guidelines for the curriculum in emerging technologies. These elements are essential for vascular education and will evolve concurrently with emerging technologies going forward.

Other programs for vascular surgery, like Objective Structured Assessment of Technical Skill[6] and Imperial College Evaluation of Procedure Specific Skill, are already used in Europe. They have a high interobserver reliability and the ability to discriminate between level of training.[7]

The work presented in this study is the next important step of the validation work by Duran et al,[8] which was first introduced in 2015. The aim in this phase of our efforts was to test the reliability of the model in assessing the performance of endovascular trainees outside of a controlled laboratory setting. After a design freeze, the model was evaluated in a "real-life" uncontrolled setting to grasp the

From the Methodist DeBakey Heart & Vascular Center, Houston Methodist Hospital, Houston[a]; the Department of Vascular Surgery, University Medical Center Utrecht, Utrecht[b]; the Department of Mechanical Engineering, Mechatronics and Haptic Interfaces Laboratory, Rice University, Houston[c]; and the Department of Vascular Surgery, Louisiana State University School of Medicine, New Orleans.[d]

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Correspondence: Viony M. Belvroy, MD, Houston Methodist Hospital, 6550 Fannin St, Houston, TX 77030 (e-mail: vionybelvroy@hotmail.com).

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ability of the model to be deployed in a meaningful way to individual programs. This work is a crucial step toward implementation of the model as an assessment tool during residency programs in the near future.

METHODS

Methods used for this study are based on the previously published article by Duran et al.[8] The model was developed by members of the Association of Program Directors in Vascular Surgery. They created a list of skills necessary for endovascular trainees to perform basic endovascular tasks. The model was tested in a virtual reality environment, and the eight different tasks are laid out in Table I.

Study participants. There were 52 participants in this study (40 male, 12 female). Based on their endovascular experience, the participants were divided into three groups: novices (<50 endovascular cases), intermediates (50-500 endovascular cases), and experts (>500 endovascular cases). A study by Lobato et al[9] reported a change in success rate after performance of 50 to 65 cases in abdominal aortic aneurysm repair or carotid artery stenting procedures.[10] Based on this article, we defined our novices and intermediates. There are no data differentiating experts from intermediates. The participants were a combination of medical students, residents, fellows, and attendings with zero to extensive experience in the vascular surgery field (30 novices, 11 intermediates, and 11 experts). The novice group consisted of 18 students, 7 starting residents, 4 starting fellows, and 1 industry professional; the intermediate group consisted of 5 residents, 3 fellows, and 3 attendings; and the experts had 3 finishing residents, 7 attending faculty, and 1 physician assistant with experience in endovascular surgery (Table II). The study participants consented to inclusion in this study according to the Rice University Institutional Review Board.

Virtual reality model. The study was performed with a virtual reality model (Fig 1). Four of the eight tasks were used in this study (Table I), which tested a variety of endovascular skills. The tasks included for validation are navigating up and over the bifurcation; imaging using oblique C-arm angulation to navigate into a third-order vessel with posterior takeoff; cannulation of a branch vessel extending from an aneurysm; and gate cannulation, which tests accurate positioning and spatial awareness in an aneurysmal space. In each task, a preselected guidewire, catheter, and sheath were used to navigate through the virtual reality model. The task was successfully completed if the guidewire, catheter, and sheath were advanced up to a preidentified success point in the virtual model and if the completion time was <5 minutes. The study participant performed a task only once and completed three or four tasks in a time schedule of around 15 to 20 minutes.

ARTICLE HIGHLIGHTS

- **Type of Research:** Prospective multicenter observational study
- **Key Findings:** The endovascular model for skill testing was used from the Fundamentals of Endovascular and Vascular Surgery curriculum; 52 tasks were completed by novices, 25 by intermediates, and 38 by experts. The difference in performance between the novice and expert groups was significant for guidewire smoothness and average guidewire velocity ($P < .001$).
- **Take Home Message:** The Fundamentals of Endovascular and Vascular Surgery model is a useful objective performance assessment tool to test competency of endovascular surgeons.

Motion analysis. Two similar systems were used to collect data for the motion analysis, the ANGIO Mentor Flex Endovascular Simulator (3D Systems, Littleton, Colo) and the ANGIO Mentor Ultimate Simulator (3D Systems). Optical sensors on the simulator recorded the translation and rotation of practice guidewires, catheters, and sheaths inserted into the device; a preloaded module contained a virtualized training model used by the Fundamentals of Endovascular and Vascular Surgery (FEVS) platform in simulated physical tool tip motions.[8] The module streamed X, Y, and Z position data of each tool tip over a TCP network connection at varying sampling rates between 15 and 60 Hz. The module also provided a means to calculate velocity by streaming the differences between adjacent position values throughout each task. Two different motion metrics were computed from the tool tip velocity data to analyze the quality of movement. Spectral arc length (SAL), a frequency domain measure of movement smoothness, is proven to be significantly correlated to experience level for endovascular procedures performed on manual, simulator, and robotic platforms.[11] The average tool tip velocity was calculated for each tool by using the tangential velocity profile. Applying these principles to guidewire and catheter tip motion analysis objectively characterized the quality of motion and correlated it with performance.[12]

Performance assessment. Performance was evaluated in four tasks, measuring the tool tip position and velocity on the virtual model. Average tool tip velocity and movement smoothness evaluated in the frequency domain are validated parameters defining proficiency of movement.[11,13] Movement smoothness is measured as SAL. Another measure of performance is idle time. This is defined as the total time that the surgical tools are stationary, which correlates to experience level.[14] The final metric to assess performance is the path length, which

Table I. The eight fundamental tasks for endovascular trainees, created by the Fundamentals of Vascular Surgery Task Force of the Association of Program Directors in Vascular Surgery

Task	Description
1	Navigate up and over a bifurcation
2	Reshape a reverse curve catheter (task requires anteriorly oriented, downsloping branch cannulation)
3	Imaging using oblique C-arm angulation (navigate into a third order vessel with posterior takeoff)
4	Cannulate right angle branch
5	Cannulate a branch vessel extending from an aneurysm
6	Maintain wire position during catheter/device exchange
7	Gate cannulation (tests accurate positioning and spatial awareness in aneurysmal space)
8	Cannulate off of type 3 arch anatomy (reshape catheter in the arch)

From Duran C, Estrada S, O'Malley M, Sheahan MG, Shames ML, Lee JT, et al. The model for Fundamentals of Endovascular Surgery (FEVS) successfully defines the competent endovascular surgeon. J Vasc Surg 2015;62:1660-6.e3.

Table II. Number of tasks performed by participants of each experience level

	Novice (n = 30)	Intermediate (n = 11)	Experts (n = 11)	Total
Task 1	29	9	10	48
Task 3	14	5	11	30
Task 5	5	7	10	22
Task 7	4	4	7	15
Total	52	25	38	115

measured the length of the tool tip motion within the virtual model.[15] The data were filtered and interpolated to calculate the metrics. Trials containing critical tool manipulation errors were discarded as these was not relevant to validate the model.

Data analysis. The data were analyzed using MATLAB and Statistics Toolbox Release 2012b (MathWorks, Natick, Mass). Normality was tested using Q-Q plots, and the homogeneity of variance was satisfied by O'Brien test. Comparison between groups was tested using the one-way independent measures analysis of variance. Tukey honest significant difference was performed to test metrics that produced significant analysis of variance results. When a participant completed more than one task, the data were averaged and compared between groups. Motion data from tasks containing critical failures were excluded, and outlier removal was not performed. Correlations were tested using a linear regression model.

RESULTS

A total of 52 study participants were divided into three groups on the basis of their experience: 30 novices, 11 intermediates, and 11 experts. The number of tasks completed per group was 52 by novices, 25 by intermediates, and 38 by experts. Their performance was analyzed, and a significant difference was found for SAL in guidewire ($P < .001$), average velocity ($P < .001$), and idle time ($P < .001$; Table III; Fig 2). Post hoc tests showed a statistically significant difference between novices and experts and between intermediates and experts but not between novices and intermediates. No statistically significant differences were found for the tool catheter in smoothness and average velocity or for the guidewire in path length across groups.

A linear regression model was built and showed a positive correlation between SAL and average velocity of the guidewire ($r(42) = 0.72$; $P < .001$). Likewise, there was a positive correlation between SAL and idle time ($r(42) = 0.70$; $P < .001$); however, there was no correlation between SAL and path length.

DISCUSSION

The aim of this study was to provide further validation of the FEVS in a virtual reality model, which was first published by Duran et al[8] in 2015. The prior validation of the model had been performed in a controlled environment in an experimental laboratory. The goal of this work was to broaden the evaluation of the model in a setting that more closely mirrored the real-world nonexperimental space. Even under these conditions, the model continues to differentiate novices from experts on the basis of their experience and handling of the guidewire and catheter tools, measured as smoothness and average velocity. This further supports the notion that the model offers a useful instrument to test competency of endovascular surgeons and can be implemented in residency programs.

In the previously published study by Duran et al,[8] performance was assessed between competent and noncompetent. In this study, the participants were divided into three groups, novices, intermediates, and experts, on the basis of their experience and case load. There was a statistically significant difference for novices vs experts and intermediates vs experts. However, no difference was found between novices and intermediates. This shows that the important differentiation might be between the competent (expert) and the noncompetent (novices and intermediates), which was the finding of our initial work. In the context of the intent of the model, there may indeed be no value in any other grouping.

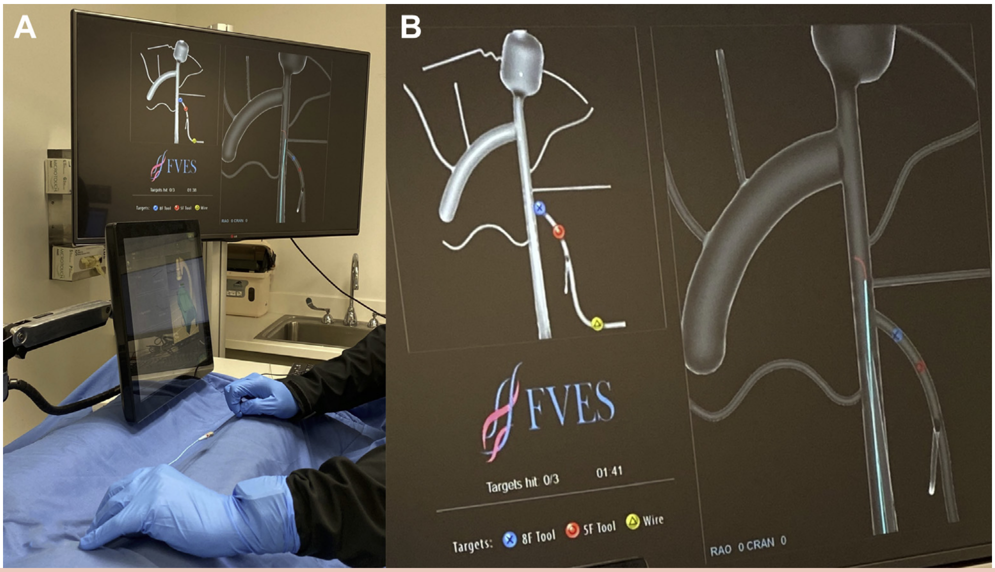

Fig 1. Overview **(A)** of an endovascular trainee working with the ANGIO Mentor Ultimate Simulator (3D Systems, Littleton, Colo) completing different tasks **(B)** by inserting the tools to the correct end point (guidewire, *yellow*; catheter, *red*; sheath, *blue*). *FEVS*, Fundamentals of Endovascular and Vascular Surgery.

Table III. Results of performance metrics

Metric	Outcome	Effect size (Cohen's *f*)
SAL	$F(2, 42) = 9.38$; $P < .001$	0.67
Average velocity	$F(2, 42) = 10.66$; $P < .001$	0.71
Idle time	$F(2, 42) = 8.18$; $P < .001$	0.62
Path length	$F(2, 42) = 2.67$; $P = .200$	0.28

SAL, Spectral arc length.
Calculated with one-way analysis of variance and effect size (Cohen's *f*).

The objective is essentially simply to identify trainees who are capable of performing a series of fundamental skills.

The main limitation of this work is that not all modules in the FEVS were tested in every participant, and so a complete assessment of performance is not possible. We cannot verify that each module effectively reflects competency; however, it does show a difference in technical proficiency. Furthermore, we can assert that modules evaluated in our initial studies remain valid in this analysis. Although tool tip motion is able to differentiate competent from incompetent, it is unclear whether all metrics are valid or appropriately weighted for task validation. Ideally, a psychometric analysis has the potential to assess this latent question because although motion capture does provide an objective evaluation, it lacks the critical appraisal of the value of a specific metric.[16] To continue the validation process, the goal is not only to recruit more participants but to refine our metrics by assessing the correlation between the tool tip movements and performance.

The modules within the FEVS reflect a range of skills and difficulty. The importance of evaluating each individual module is therefore critical to understanding that the differentiation between competent and noncompetent remains consistent throughout. As we continue to gauge the consistency of this model, the number of participants evaluated will help define whether we are indeed testing "endovascular aptitude."

CONCLUSIONS

We are confident that the FEVS model is capable of differentiating competent from noncompetent endovascular operators. Further studies and continued data collection and analysis will broaden our understanding of each module's task. We will continue to report on this research as it evolves because we remain certain that the need to have an objective skills assessment tool is an imperative component of determining a trainee's level of competence.

AUTHOR CONTRIBUTIONS

Conception and design: VB, BM, MS, MO, JB
Analysis and interpretation: VB, BM
Data collection: VB, BM
Writing the article: VB
Critical revision of the article: BM, MS, MO, JB
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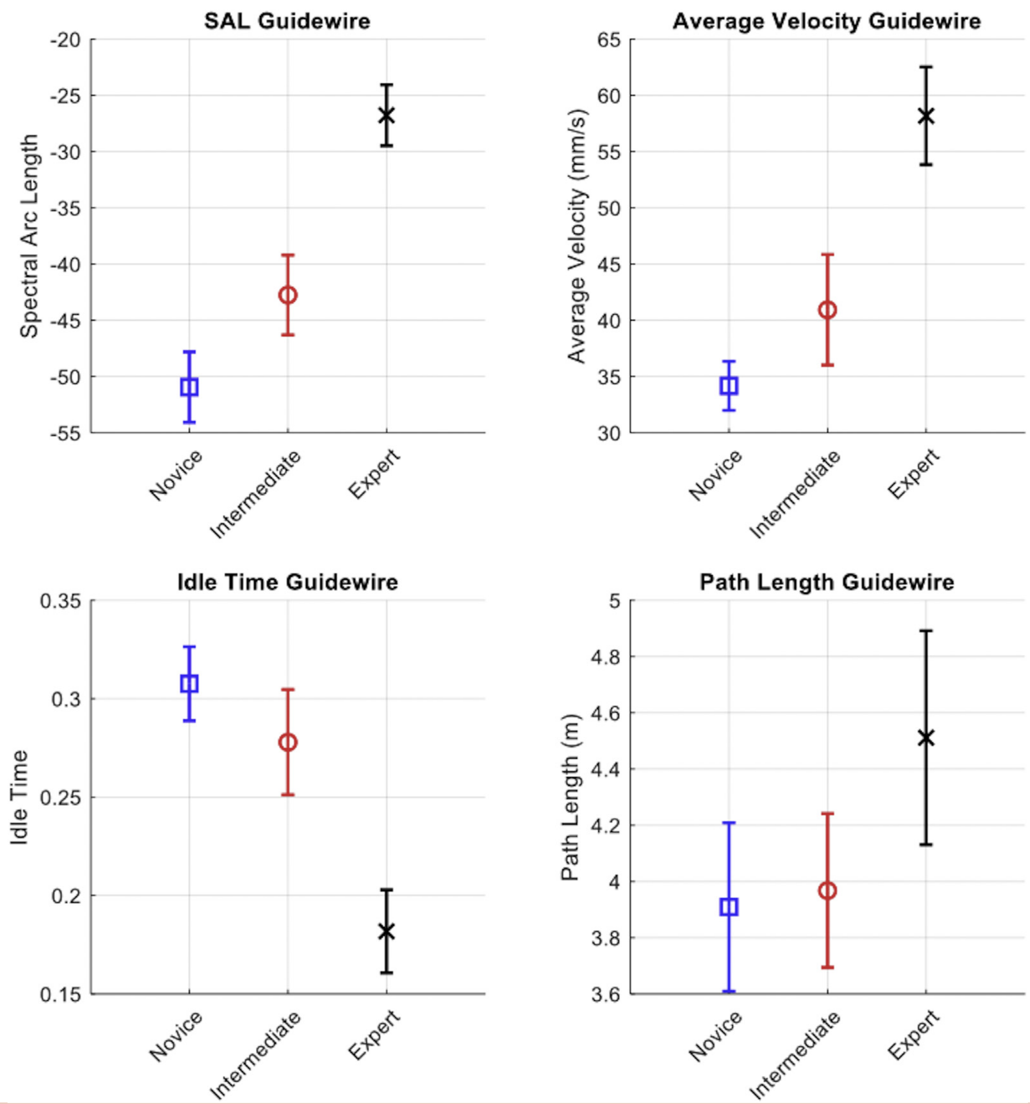

Fig 2. Plots showing the mean and standard error of the outcome measures for the guidewire in spectral arc length (*SAL*), average velocity, idle time, and path length for each experience level.

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