

ORIGINAL ARTICLE

Certification of Basic Skills in Endovascular Aortic Repair Through a Modular Simulation Course With Real Time Performance Assessment

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WHAT THIS PAPER ADDS

This paper presents a new modular simulation based course in standard endovascular aortic repair (EVAR), and its effectiveness is proven. This course uses a combination of concurrent and terminal feedback styles. EndoVascular Aortic Repair Assessment of Technical Expertise, a research based assessment tool, was evaluated and found to be applicable for real time assessment of technical skills in a standardised course setting. Finally, individual learning curves were evaluated when learning standard EVAR procedures were practised in a simulated environment.

Objective: Endovascular aortic repair (EVAR) is being used increasingly for the treatment of infrarenal abdominal aortic aneurysms. Improvement in educational strategies is required to teach future vascular surgeons EVAR skills, but a comprehensive, pre-defined e-learning and simulation curriculum remains to be developed and tested. EndoVascular Aortic Repair Assessment of Technical Expertise (EVARATE), an assessment tool for simulation based education (SBE) in EVAR, has previously been designed to assess EVAR skills, and a pass limit defining mastery level has been set. However, EVARATE was developed for anonymous video ratings in a research setting, and its feasibility for real time ratings in a standardised SBE programme in EVAR is unproven. This study aimed to test the effect of a newly developed simulation based modular course in EVAR. In addition, the applicability of EVARATE for real time performance assessments was investigated.

Methods: The European Society of Vascular Surgery (ESVS) and Copenhagen Certification Programme in EVAR (ENHANCE-EVAR) was tested in a prospective cohort study. ENHANCE-EVAR is a modular SBE programme in EVAR consisting of e-learning and hands-on SBE. Participants were rated with the EVARATE tool by experienced EVAR surgeons.

Results: Twenty-four physicians completed the study. The mean improvement in EVARATE score during the course was +11.8 (95% confidence interval 9.8 – 13.7) points ($p < .001$). Twenty-two participants (92%) passed with a mean number of 2.8 ± 0.7 test attempts to reach the pass limit. Cronbach's alpha coefficient was 0.91, corresponding to excellent reliability of the EVARATE scale. Differences between instructors' EVARATE ratings were insignificant ($p = .16$), with a maximum variation between instructors of ± 1.3 points.

Conclusion: ENHANCE-EVAR, a comprehensive certifying EVAR course, was proven to be effective. EndoVascular Aortic Repair Assessment of Technical Expertise (EVARATE) is a trustworthy tool for assessing performance within an authentic educational setting, enabling real time feedback.

Keywords: Assessment, Certification, Endovascular aortic repair, Feedback, Simulation based education

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INTRODUCTION

The number of endovascular aortic repair (EVAR) procedures exceeds open procedures in treating infrarenal abdominal aortic aneurysms.¹ Technical skills in EVAR can be practised since the introduction of realistic endovascular simulators, and simulation based education (SBE) has been shown to improve EVAR performance.^{2–4}

Reaching a defined mastery level in a safe environment, such as a simulated setting, is essential in commonly used and high stake procedures before applying these skills to patients.⁵ Simulation based education within vascular surgery in Europe was recently investigated in a needs assessment documenting EVAR to be among the most needed procedures to be practised in a simulator.⁶ In order to assure standardised feedback and that mastery level is reached, validated real time assessment is needed.⁷ Endo-Vascular Aortic Repair Assessment of Technical Expertise (EVARATE), an assessment tool for SBE in EVAR, was developed in 2017 following a Delphi process; a pass limit was subsequently established to define a mastery level.⁸ The EVARATE tool was developed for anonymous offline video rating; however, its feasibility in a highly standardised SBE programme in an authentic educational environment has not yet been proven.⁹ In addition, EVARATE has not previously been used for real time testing in a certifying SBE programme in EVAR.

Simulation based education in EVAR can improve performance,³ but SBE is a expensive and time consuming investment for organisers and participants. Hence, there is a need for evidence based training with an effective educational strategy and curriculum design, and proven attainment of learning objectives.¹⁰ Maertens *et al.* developed a comprehensive proficiency based modular SBE course for peripheral endovascular procedures and found it to be cost effective and efficient in improving performance.^{11,12} The effectiveness of such a course for elective infrarenal EVAR, with a modular curriculum consisting of e-learning and pre-defined simulations, has not been established.

This study aimed to assess the effectiveness of a newly developed modular course in standard EVAR and to evaluate EVARATE as a real time assessment tool in that setting.

MATERIALS AND METHODS

Study design

This study was a prospective cohort study.

Study population

International vascular surgeons and vascular surgical trainees with limited experience in EVAR (maximum of five supervised EVAR procedures and no independent EVAR procedures) were eligible. Previous participation in SBE in EVAR was allowed. Participants were recruited from 01 April 2022 to 31 March 2023 via announcements on the European Society of Vascular Surgery (ESVS) homepage, Twitter, and LinkedIn, and through emails to ESVS members. All potential participants were screened through a pre-course

survey to ensure that they met the inclusion criteria. If eligible, participants underwent a 20 minute online interview with the course convenors (RS, MS) to confirm their EVAR experience, the course's career relevance, and their commitment to learning standard EVAR, and to obtain informed consent to use data for research purposes.

Rater training

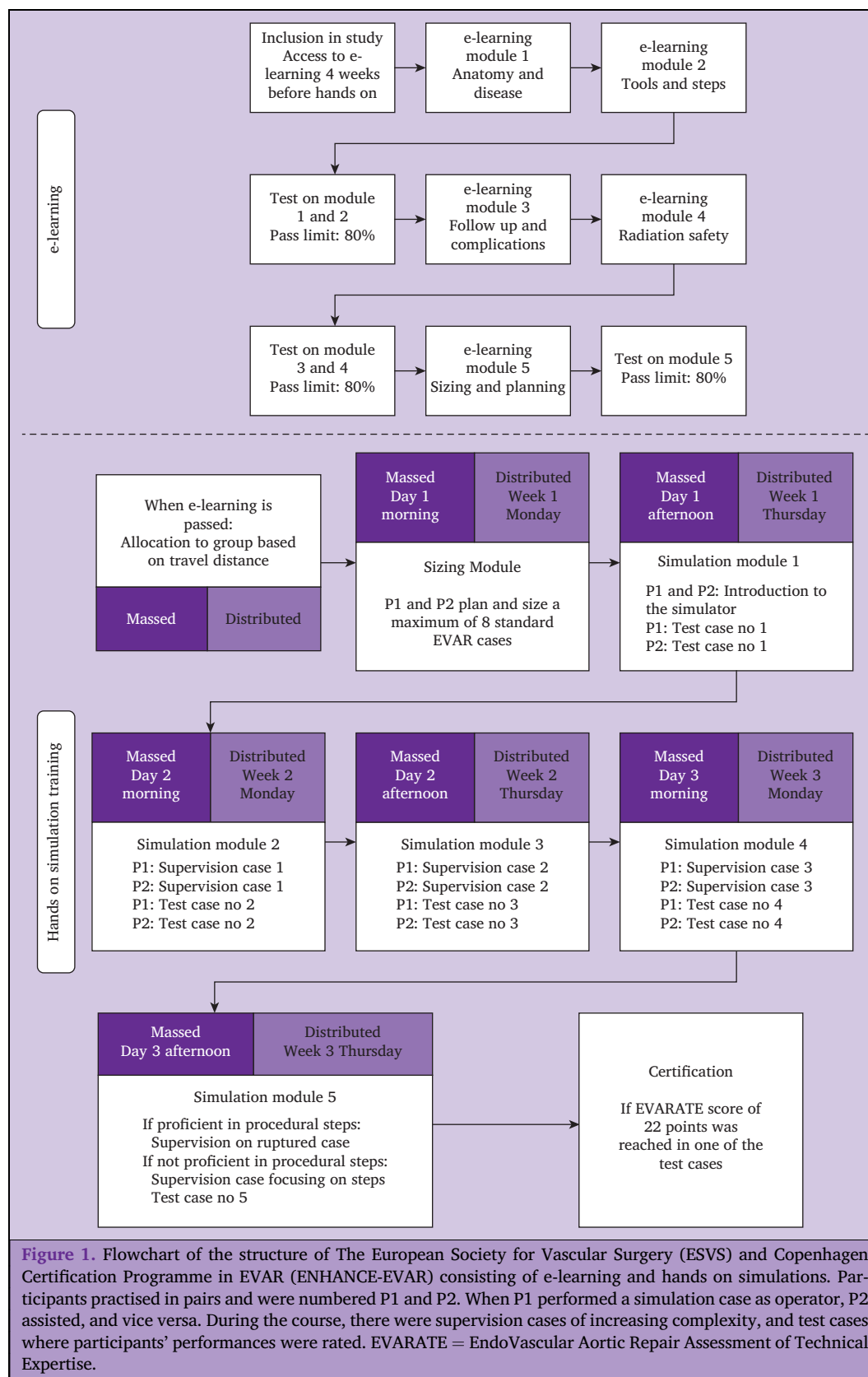
The course instructors were all experienced EVAR surgeons, defined as EVAR surgeons with > 10 years of independent EVAR practice. The instructors completed systematic rater training to familiarise and prepare them for EVARATE real time assessments. The rater training consisted of an online EVARATE instructions for use and videos of each of the seven EVARATE steps, exemplifying unacceptable (1 point), acceptable (3 points), and excellent (5 points) performances. Before the course, all instructors met in person and discussed discrepancies and uncertainties until consensus was reached.

Content

The course consisted of an e-learning programme and subsequent hands on simulations. The e-learning consisted of five modules and three multiple choice tests. Each multiple choice test required 80% correct answers to continue to the next module. If the participant failed the test, they had to retake the e-learning and the test. Only participants who passed the e-learning were invited to continue with the hands on simulations. The content of the e-learning modules is summarised in Figure 1.

The hands on simulations comprised six modules limited to 3.5 hours each: one module covering sizing and planning for EVAR and five procedural modules in the ANGIO Mentor Flex II simulator (Simbionix, SurgicalScience Sweden AB, Göteborg, Sweden). Sizing and planning were performed on dedicated workstations (3Mensio Vascular 10.3, Pie Medical Imaging BV, Maastricht, The Netherlands) using eight anonymised computed tomography scans of AAA patients meeting the instructions for use of the Medtronic Endurant IIs stent graft (Medtronic, Santa Rosa, CA, USA). The five EVAR simulation modules were completed in pairs, as the participants alternated as operator and assistant. The participants were paired according to experience and the groups were fixed for the whole course. Only simulated Medtronic Endurant II grafts were used.

Two types of teaching strategies were used: test cases and supervision cases. The test cases remained consistent throughout the course, which made it easier to track participants' progress and ensured that any changes in EVARATE scores were not influenced by case complexity. During test cases, the participants did not receive help from the instructor unless this was needed to complete the case. The instructor observed and rated the participant with EVARATE and gave structured formative feedback after completing the case (terminal feedback). During the course, each participant would complete at least four identical test cases. The supervision cases displayed increasing complexity and



varying learning outcomes from case to case. During supervision cases, the participants were allowed to ask questions, discuss approaches, and gain tips and tricks, and were not rated but received formative feedback (concurrent feedback).

The content of the simulation modules and the test distribution are illustrated in Figure 1. The last and fifth simulation module was determined based on the participant's performance: if confident in the standard case (meaning test scores above the pass limit), participants were allowed to proceed to a ruptured EVAR SBE module. Otherwise, a standard case was practised again, followed by a fifth test case. Therefore, each participant would complete at least four test cases and four supervision cases as operator, and the same number of cases as assistant during the programme.

Scheduling of training

Depending on the travel distance to the simulation centre, participants were assigned to either six modules distributed over three weeks or to a massed schedule, completing the same six modules over three consecutive days.

Assessment

Participants were rated in real time with the EVARATE tool⁸ during the four or five test cases. Each of the seven steps was rated on a five point Likert scale, allowing a minimum score of 7 points and a maximum score of 35 points. The pass limit was defined as 22 points.⁹ As an amendment to the original tool, supervisor takeover reduced the respective step score to one point, irrespective of the rating.

Course evaluation

Each participant completed an evaluation form immediately after the study. Questions were rated on a five point Likert Scale, and others allowed free text answers.

Data analysis and statistics

Numerical data were presented as mean \pm standard deviation and categorical data as count (n) with percentage. Progress in EVARATE scores of each participant was depicted as classic learning curves. Radar charts were used to visualise specific performances in the seven EVARATE steps between participants with the same EVARATE score. To get a nuanced learning curve, individual radar charts were depicted for each participant. Mean EVARATE scores in the two groups were compared for each test in the course and depicted with and without correction for the number of procedures performed prior to the study. The internal consistency of EVARATE was tested with Cronbach's alpha analysis; a value > 0.90 was defined as excellent reliability.¹³ In addition, instructors' ratings were assessed with a likelihood ratio test of two mixed linear models, of which one model contained the rater as a random variable. All statistical analyses were performed in RStudio version 2022.12.0.353 (Posit Software, PBC, Boston, MA, USA).

Ethics

Participants received verbal and written information about the study and signed an informed consent form. The Ethical Committee of the capital region of Denmark reviewed the study protocol and waived ethical approval (ref. H-21063651).

RESULTS

Twenty-four participants were included: 12 followed a distributed and 12 followed a massed training schedule. All participants completed and passed the pre-course e-learning.

Demography

Demographics are outlined in Table 1. Participants' mean age was 36.1 ± 4.8 years, and 16 (67%) had never performed an EVAR procedure as a primary surgeon. Seven were vascular surgeons and 17 were vascular surgical trainees. Participants who received the massed training schedule were more experienced than those who received the distributed training. In the distributed group, one participant (8%) had > 5 years of vascular surgical training compared with eight participants (67%) in the massed group ($p = .012$). No participants in the distributed group had performed an EVAR as primary operator compared with eight (67%) in the massed group ($p = .002$).

Performance

All participants completed the hands on modules within the time frame. The mean baseline score was 10.6 ± 2.5 for the distributed group and 15.7 ± 3.9 for the massed group

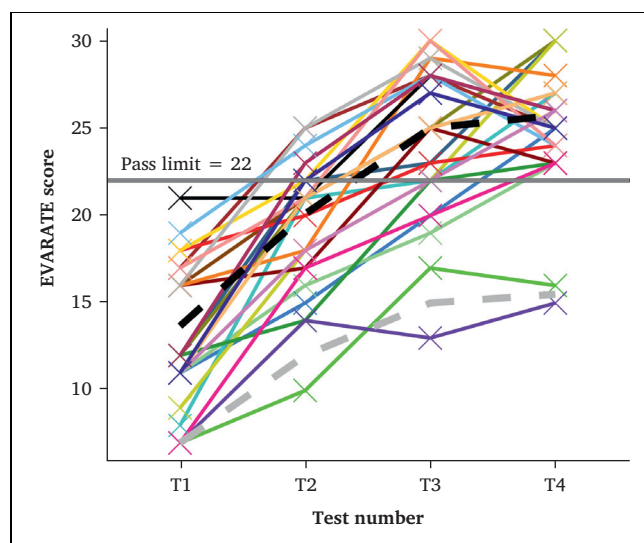


Figure 2. Individual learning curves of novices learning endovascular aortic repair. Performance scores obtained with the assessment tool, EndoVascular Aortic Repair Assessment of Technical Expertise (EVARATE), of each participant during the four tests are shown. The black horizontal line is the pass limit at a score of 22 points, the black dashed line is the mean scores of passed participants, and the grey dashed line is the mean scores of failed participants.

Table. Baseline characteristics of the 24 participants attending the European Society for Vascular Surgery (ESVS) and Copenhagen Certification Programme in endovascular aortic repair (EVAR)

	Total (n = 24)	Distributed (n = 12)	Massed (n = 12)	p value
Age – years	36.1±7.8	34.1±7.2	38.2±8.3	.21
Sex – male	10 (42)	3 (25)	7 (58)	.21
<i>Years of vascular surgical training</i>				.012
< 1	2 (8)	1 (8)	1 (8)	
1–2	6 (25)	5 (42)	1 (8)	
2–3	4 (17)	4 (33)	0 (0)	
3–4	1 (4)	1 (8)	0 (0)	
4–5	2 (8)	0 (0)	2 (17)	
> 5	9 (38)	1 (8)	8 (67)	
<i>EVAR procedures as assistant – n</i>				.84
None	2 (8)	1 (8)	1 (8)	
1–5	4 (17)	3 (25)	1 (8)	
6–10	4 (17)	2 (17)	2 (17)	
11–20	4 (17)	2 (17)	2 (17)	
> 20	10 (42)	4 (33)	6 (50)	
<i>EVAR procedures as primary surgeon under supervision – n</i>				.002
None	16 (67)	12 (100)	0 (0)	
1–5	8 (33)	0 (0)	8 (67)	
<i>Endovascular peripheral interventions as assistant – n</i>				.59
None	1 (4)	1 (8)	0 (0)	
1–5	1 (4)	1 (8)	0 (0)	
6–10	2 (8)	1 (8)	1 (8)	
11–20	7 (29)	4 (33)	3 (25)	
> 20	13 (54)	5 (42)	8 (67)	
<i>Endovascular peripheral interventions as primary operator under supervision – n</i>				.008
None	8 (33)	8 (67)	0 (0)	
1–5	4 (17)	2 (17)	2 (17)	
6–10	6 (25)	1 (8)	5 (42)	
11–20	4 (17)	1 (8)	3 (25)	
> 20	2 (8)	0 (0.0)	2 (17)	

Data are presented as mean ± standard deviation or n (%). Participants are grouped according to training schedule as either distributed or massed. EVAR = endovascular aortic repair.

($p < .001$), with no outliers identified. During the course, the difference in performance diminished with a mean score in the final test of 25.7 ± 3.9 in the distributed group and 24.1 ± 3.2 in the massed group ($p = .29$). The mean change in EVARATE score from baseline to test number four was 11.8 (95% CI 9.8 – 13.7). One participant following the distributed and one participant following the massed schedule did not reach proficiency level. Thereby, twenty-two participants (92%) reached the pass limit within the duration of the courses. The mean number of test attempts necessary to pass was 2.8 ± 0.7 . Individual learning curves are depicted in Figure 2, showing different progression between the participants' four test cases.

Reliability of rater assessment

The Cronbach's alpha coefficient of the EVARATE tool was 0.91, corresponding to excellent reliability of the tool. The likelihood ratio test of the two mixed linear models of EVARATE scores was non-significant ($p = .16$), indicating that the EVARATE scoring, not differences in rating practice between the individual instructors, significantly influenced the assessments. The mean variations in ratings between instructors ranged from ± 1.3 points.

Procedural step performances

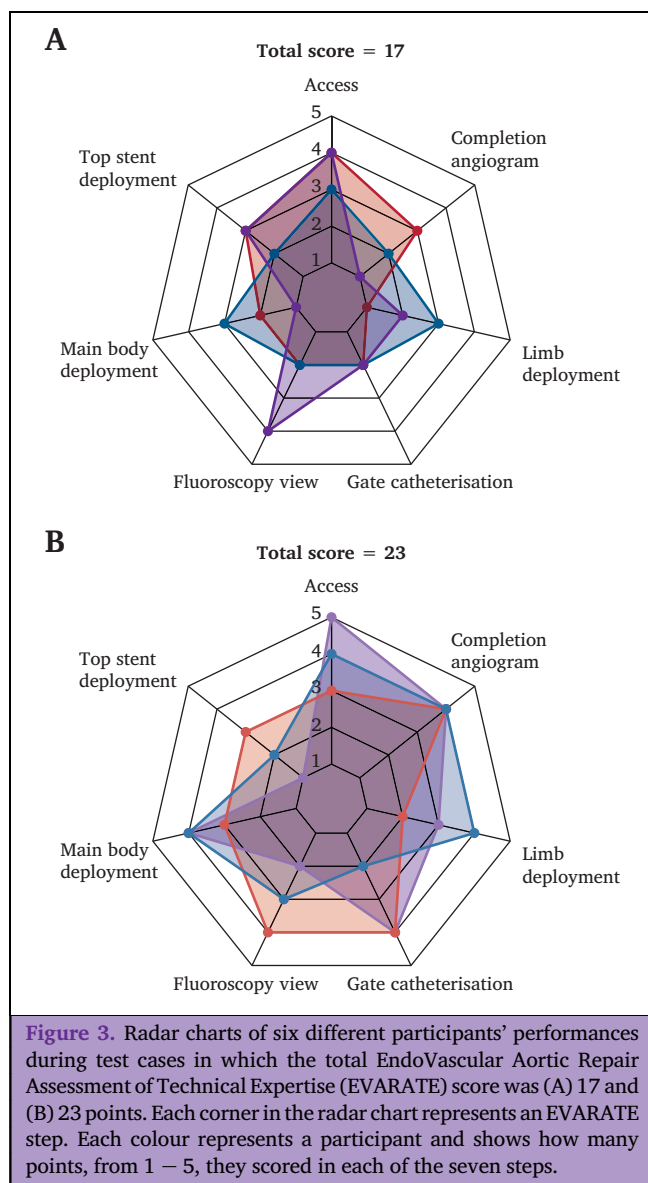
To exemplify the concept of a radar chart as a more subtle tool for assessing skills progression, the two radar charts in Figure 3 show three random participants who scored 17, and another three who scored 23. Despite having identical EVARATE scores, the participants exhibited varying degrees of acquired skills within the seven EVARATE steps. Figure 4 depicts, with radar charts, the individual performances at each of the seven EVARATE steps for each participant.

Massed vs. distributed

Learning curves and performances of participants following massed vs. distributed training schedules are compared unadjusted in Figure 5A and adjusted for previous experience in Figure 5B. The performances in the two groups were comparable with overlapping 95% confidence intervals.

Course evaluation

Participants were generally satisfied with the course and agreed that it made them more confident in the procedural steps. Most participants (96%) agreed that passing this ENHANCE-EVAR course during vascular surgical training



should be mandatory, and 92% found the distribution between supervision and test cases to be good. Participants had positive responses to the question How did you feel about being rated during the course?, such as Ratings and structured feedback made me focus more and Made me more motivated. One participant replied: It was a little overwhelming, but this is the right way to do it. Details on evaluation can be seen in the [Supplementary Table](#).

DISCUSSION

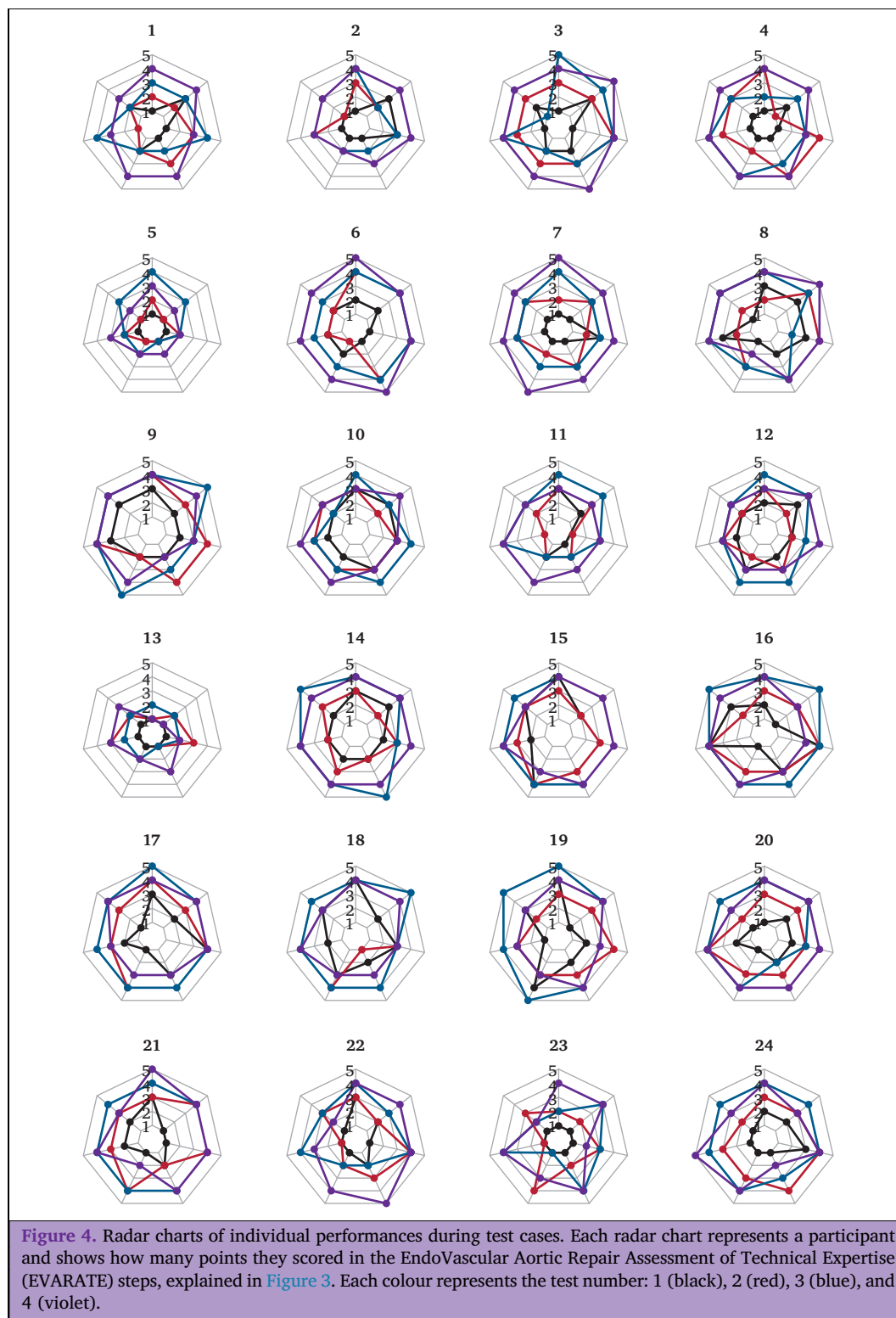
This study presented the structure of a modular course in standard EVAR, ENHANCE-EVAR, and the effectiveness of the course and applicability of a validated assessment tool for real time ratings was investigated. Three findings were evident: firstly, the course design of ENHANCE-EVAR was effective, leading to 92% of participants reaching proficiency level; secondly, EVARATE was feasible for real time assessment of EVAR performance in an authentic learning environment; thirdly, individual learning curves were

identified, and radar charts seemed promising for a more nuanced description of acquired skills.

Within the timeframe of the course, 92% of participants reached the EVARATE pass limit and were subsequently certified. In another SBE course on open aortic repair, 50% reached the pass limit.¹⁴ The two courses had fundamentally different designs, as the open aortic repair course contained four test cases, no supervision cases between the test cases, and standardised feedback was only given after the procedure. In ENHANCE-EVAR, the number of cases was doubled and two types of feedback were given. During supervision cases, concurrent feedback was given, defined as feedback given during the procedure. During test cases, terminal feedback was given, defined as feedback given after the procedure.¹⁵ It has been hypothesised that terminal feedback is superior to concurrent feedback, as it allows the participant to learn from their mistakes and makes them less dependent on feedback to complete the procedure.¹⁶ On the other hand, concurrent feedback is thought to facilitate technical skills during the early skill acquisition state of learning.¹⁷ It remains unknown whether a mixture of the two styles would be better.¹⁵

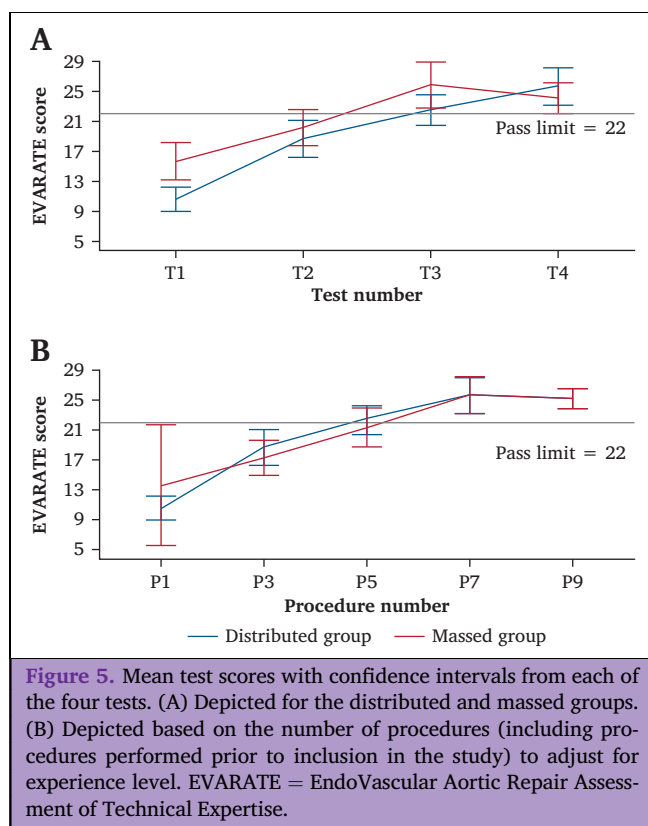
Endovascular aortic repair is a technically intricate procedure, underlining the importance for participants to reach mastery level before performing real cases.^{5,6} In the ENHANCE-EVAR programme, two (8%) did not reach the pass limit within the course's timeframe, but they may have reached the pass limit if training time was unlimited. An example of mastery learning has been demonstrated in an SBE programme on endovascular treatment of peripheral arterial disease, where participants practised during working hours and at their own pace until the proficiency level was reached.^{11,12} However, it is difficult to plan such courses, as trainees need different training volumes to pass. In contrast, it is hypothesised that some people might never be able to reach proficiency level within specific procedures, despite the amount of training and the structure of the course.¹⁸ Given that perspective, 8% might be an expected percentage for failing. Nevertheless, these results underline the need for assessments to ensure proficiency.

Classic learning curves were presented to give an overview of the total EVARATE scores, and in depth EVARATE performances were depicted with radar charts. The radar charts enabled a nuanced understanding of individual participants' learning by showing specific scores in each EVARATE step. The radar charts showed that participants underperformed in different steps at different modules in the course. [Figure 4](#) provides a visual overview of the 24 participants and illustrates how radar charts facilitated an outline of the participants' development during the course. It can be seen that course participants 2, 5, and 13 stand out as slower learners and that adjusting the training schedule or duration might have been beneficial. This visualisation of performance provides a detailed analysis of the trainee's performance, identifying strengths and weaknesses. It can improve feedback and give participants a visual explanation of their learning progress.^{19,20} As seen in [Figure 3](#), participants performed differently despite having



the same total score. The structure of future courses should focus on individualised feedback, allowing deliberate practice in a focused area during supervised cases to improve learning outcomes. Some participants underperformed in specific steps, despite having reached the pass limit of EVARATE; perhaps steps should be weighted by their importance to improve the quality of this assessment tool?²¹

In the present study, performance scores obtained during distributed and massed training schedules were comparable when adjusting for the number of procedures performed before the course. One theory suggests that the risk of cognitive overload is lower in distributed training compared with massed training, and that spaced training sessions in distributed practice may improve learning.^{22,23} However, other studies could not show differences in skill acquisition



between massed and distributed training schedules.^{24,25} Based on the results of this study, it is suggested that an SBE EVAR course could be safely scheduled according to participants' preferences and thereby ease the implementation of SBE.

Being assessed and receiving feedback can be stressful for the learner;²⁶ however, the current evaluation showed that performance assessments made participants more motivated. This positive effect of assessment on learners' motivation is a well known phenomenon.^{27–29} It seems that the motivational factor of assessment can incentivise learners to make more of an effort.

An obvious limitation of this study was the limited sample size of 24 participants. Recruitment was limited by the number of participants who met the inclusion criteria, the opportunity to be released from clinical duties, and the expenses associated with attending this course. Inter- and intrarater variability were not assessed; however, the EVARATE tool demonstrated an acceptable inter-rater variability with an intraclass correlation coefficient of 0.68 in a previous study.⁹ In addition, consistent ratings across instructors were confirmed by mixed linear model analysis, and the internal consistency of EVARATE was concluded to be excellent based on Cronbach's alpha analysis. Coincidentally, the participants in the massed group had performed more EVAR procedures prior to the programme than the distributed group; this difference was corrected for without finding any differences between groups. Participants were tested on the same case throughout the course, which might have led to familiarisation with the case and explain

some of the improvements. On the other hand, a drop in performance scores was seen for some participants, despite this familiarisation. Only Endurant devices were used for didactic reasons. Mastering complex anatomy and several EVAR devices was beyond the scope of the ENHANCE programme, which aimed to certify essential competencies in basic EVAR. Transfer of skills from the simulation centre to the hybrid room was not tested, as this was not logistically possible, neither was cost effectiveness, although previous endovascular simulation training in lower limb interventions has been proven to be cost effective.¹⁰ Retention testing was not a scope of the present study, as it would be logistically challenging to test skills among international participants and to correct for different clinical exposure. It was recently shown that retention assessment of basic endovascular skills after SBE was challenging due to lack of data on clinical exposure.³⁰ Pairings of participants were based on experience level, which could have potentially influenced the results. Finally, access and haemostasis were not practised or assessed, as this is not a feature in the Angiomentor simulator.

Conclusion

ENHANCE-EVAR is a modular, certifying, fixed duration SBE programme, certifying vascular surgeons and vascular surgical trainees in basic EVAR skills before continuing their training in a clinical setting. Although most participants passed the programme, analysis of the acquired skills exposed varying degrees of proficiency within the procedural steps. EVARATE was reliable for real time evaluations and to study individual performances. It is suggested that EVARATE be improved by adding a minimum requirement score in each procedural step, and to ongoingly evaluate and tailor the participants' training at an individual level.

CONFLICTS OF INTEREST

Authors RS, JL, MS, and JE report no relevant conflicts of interests. TR reports consultant at COOK, Bentley; grants from COOK, GORE, Bentley; advisory board Artivion. lvH is supported by a Senior Clinical Fellowship (802314N) of the Fund for Scientific Research – Flanders, Belgium; honoraria for consulting and training, Medtronic, Tolochenaz, Switzerland.

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APPENDIX A. SUPPLEMENTARY DATA

Supplementary data to this article can be found online at <https://doi.org/10.1016/j.ejvs.2023.11.016>.

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