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Capturing the Essence of Developing Endovascular Expertise for the Construction of a Global Assessment Instrument

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Abstract *Objectives:* To explore what characterises the development of endovascular expertise and to construct a novel global assessment instrument.
Design: Literature review and an experimental study.
Materials and methods: The literature was searched for information regarding available global rating scales (GRSs); scientific societies' official statements on endovascular competence; and task analyses of endovascular procedures. In the experimental study, clinicians performed a video-recorded simulated iliac-artery stenting procedure. Subsequently, by using the method of retrospective verbalisation, the clinicians were interviewed while watching their performance on video commenting on key issues of the construct. Data from all sources were analysed, categorised and synthesised into a novel rating scale.
Results: Available GRSs primarily included technical aspects of performance, whereas the competence statements, task analyses and clinicians' perceptions added a range of non-technical aspects. The novel rating scale SAVE (Structured Assessment of endoVascular Expertise) differs from prior scales by including issues of pre-planning; prediction of challenges; preparation of tools; management of imaging presentation; distinction of technical skills into external and internal control according to operator focus of visual attention; adaptation of strategy; clinical decision making; use of assistant; complications; inter-personal skills; and post-procedural planning.
Conclusions: The essence of developing endovascular expertise goes far beyond mere technical aspects.

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More than a decade ago, virtual reality simulators were introduced to the endovascular (EV) field. The first reports were published on carotid artery stenting,[1,2] and later, simulation of coronary,[3] renal,[4,5] lower-limb ischaemia[6] and uterine artery intervention[7] were included. Early optimism focussed on face validity and the simulators' capability of assessing performance objectively by reporting results from the built-in metrics, for example, procedure time, fluoroscopy time and volume of contrast fluid.[1,4] However, several studies failed to support these expectations as simulator metrics correlated poorly with various levels of experience indicating poor construct validity.[2,5,8–12]

Various assessment forms have been developed for evaluating procedural surgical competence based on observation of performance, that is, task-specific checklists;[12–14] global rating scales;[12–15] hybrid rating scales combining a checklist and a global scale form;[9,16] and error detection.[12,17] Assessment by checklists was found less valid as compared to assessment by global rating scales (GRS) in general surgery,[14,18] laparoscopic surgery[19] and endovascular surgery.[12] In general, checklists have been criticised for a 'ceiling effect', that is, being unable to discriminate increasing levels of clinical experience due to dichotomous scaling of assessor response leading to loss of information on competence upon rating.[20–22] Hence, checklists were suggested and applied to the early learning stages in particular.[13,20]

Several research groups have developed a GRS in the EV field (Table 1).[1,6,9,12,15,23,24] To date, there are no reports of available assessment instruments capable of discriminating performance at all stages of EV experience with reliable results. One problem of currently available GRSs might be that their focus is mainly on technical skills. However, EV procedural competence encompasses far more than mere technical skills including cognitive issues,[11] clinical decision making[25] and inter-personal skills, especially when dealing with a conscious patient.[26] Therefore, we speculate that assessment of EV competence, that reflects broader aspects as compared with current assessment instruments, might be more valid.

Hence, the aim of this study was to explore what characterises EV competence and the essence of developing EV expertise to construct a global assessment instrument.

Materials and Methods

Construction of the assessment instrument was conducted in an iterative process synthesising data from two sources: First, the literature was reviewed for prior characterisation of EV competence to compile a list of items to be included in the assessment instrument. Second, we sought EV clinicians' perceptions of key issues characterising the development of EV expertise. Data from the two sources were analysed, categorised and synthesised into a novel assessment instrument.

Literature review characterising EV competence

The following categories formed the basis of the literature search strategy:

(1) Available GRSs applied in empirical studies of EV procedures, (2) clinical competence statements from EV

Table 1 Characteristics of published global rating scales in empirical studies of endovascular procedures and their study of validity and reliability. VR — virtual reality; OR — operating room; CAS — carotid artery stenting; RAS — renal artery stenting.

	Dayal[1]	Hislop[23]	Chaer[6]	Berry[15]	Tedesco[9]	Van Herzeele[12]
Setting	Simulator	Simulator	Clinical transfer VR-OR	Sim/porcine	Simulator	Simulator
Procedure	CAS	Carotid	Iliac/femoral	Iliac	RAS	CAS
Research method for definition of Items	Expert opinion	Expert opinion	Expert opinion	Expert opinion	Expert opinion	Expert opinion
OSATS[14] influence	No	Yes	Yes	Yes	Yes	Yes
No. of items	4	6	12	9	10	8
Grading of assessor response	0–5	1–5	0–4	1–5	1–5	1–5
Description of items	No	Yes	Yes	Yes	No	Yes
Study of validity	No	Yes	No	No	Yes	Yes
Construct valid	—	No[a]	—	—	Limited[b]	Limited[c]
Study of reliability	No	Yes	No	Yes	No	Yes
Reliability coefficient (Inter-rater)	—	?[d]	—	.65	—	.84
No. of participants	21 Mixed	61 Mixed	20 Novices	12 Novices	17 Mixed	18 Mixed

[a] Performance score of 10 experts above and 13 experts below the pre-defined proficiency level.
[b] Significant difference in total performance score between low and moderately experienced ($P < 0.03$). Experts were not included in the study.
[c] Significant difference in total performance score between novices and intermediates ($P < 0.01$). No difference was found between intermediates and experts.
[d] No reliability coefficient reported.

scientific societies and (3) task analysis of EV procedures of arterial angioplasty.

A systematic literature search was made in Medline, PubMed to identify all publications on EV competence in the English, German and Scandinavian languages with the following MeSH-terms in combination: computer simulation, user—computer interface, clinical competence, training, task performance and analysis, catheterisation, angioplasty, stents, vascular surgical procedures, carotid arteries, coronary arteries, iliac artery and renal artery obstruction.

In addition, a cross-referenced manual search was conducted based on the reference lists of the initially identified publications. One author (BB) conducted the primary search, the results being checked by the other (LL).

Exclusion criteria in the three categories were reports without publication of the specific GRS, clinical competence statements from other than EV scientific societies, and task analysis of EV procedures not including arterial angioplasty.

Clinicians' perceptions of developing endovascular expertise

Clinician's perceptions of developing EV competence were gathered in an experimental study of video-recorded performances of stenting procedures in the simulator with following interview, using the method of retrospective verbalisation.[27] Data were collected from EV experts as well as from trainees. Trainees were included because they still remember the basic skills to be acquired, in contrast to experts who usually operate upon automated skills.[28]

A VIST simulator (Mentice AB, Gothenburg, Sweden) software V7.5 was set up. Two digital video cameras mounted on tripods were positioned at vantage points for recording of manipulation of EV tools and the fluoroscopic monitor (Fig. 1).

Participants familiarised with the simulator during a 15-min warm-up procedure prior to performing a simulated stenting procedure of the contralateral iliac artery. This procedure is one of the very first procedures for novices to learn and a contralateral approach necessitates crossing the aortic bifurcation, thereby increasing the technical challenges.

After the procedure, the participants first watched their video performance in total length and reported thoughts as they came to mind. Next, the video was played back for semi-structured interviewing (BB and CR). Experts were asked: "Where during the procedure do trainees typically have difficulties and what are the issues at stake?" Trainees were asked: "Where during the procedure did you have difficulties learning the technique and what are your thoughts regarding overcoming these difficulties?" The verbal reports were tape recorded and transcribed verbatim. During retrospective verbalisations, clinicians were pre-instructed to abstract from the simulated setting and report on experiences drawn from their clinical work.

Three authors (BB, CR and LL) analysed the videos and transcripts from one expert and one trainee according to the list of items based on the literature review. This process aimed at identifying additional aspects and specifying items of EV competence. Through discussions, a framework of themes and sub-themes was identified to code the data. Clinicians were included in the study until saturation was reached, that is, when inclusion of another participant contributed no novel information. Subsequently, the whole data set was coded. Finally, the authors negotiated and formulated items to be included in the final assessment instrument.

Ethics

According to The Committees on Biomedical Research Ethics of the Capital Region of Denmark, the study was not subject to ethical approval (ref. H-B-2008-FSP 21). The clinicians gave informed consent to participate in the study.

Results

In the following, the contribution from each source of information and the resulting novel assessment instrument are described under separate headlines: literature review, clinicians' perceptions and the novel assessment form. The results are presented in Table 2, categorised in themes and sub-themes.

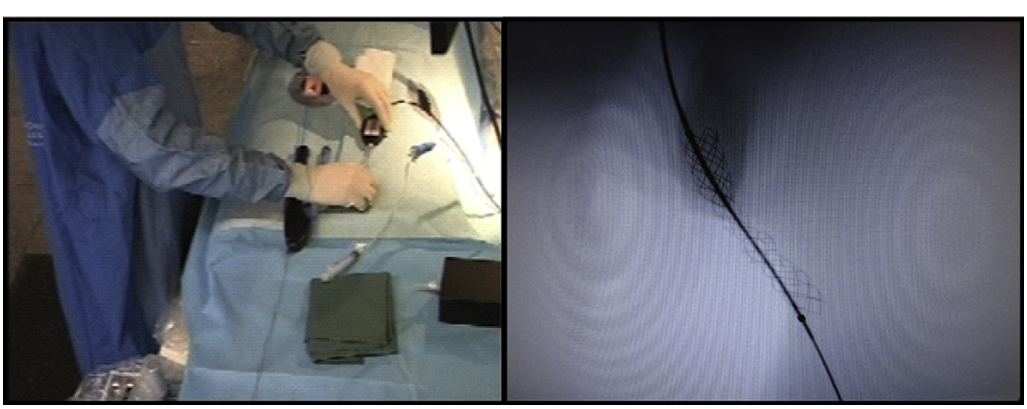

Figure 1 AV recording of a simulated endovascular procedure with stent deployment. Left: handling of tools (external technique). Right: the fluoroscopic view (internal technique).

Table 2 Themes and sub-themes characterising endovascular (EV) competence. Information was gathered from a review of literature and an experimental study of clinicians in Interventional Radiology with different levels of EV experience.

Themes and sub-themes	Literature characterising endovascular (EV) competence			The study of clinicians with different levels of EV experience (*N* = 7)
	Global rating scales (1,6,9,12,15,23)	Clinical competence statements (25,29-32)	Task analysis (33,34)	
Pre-procedure				
Gain vascular access		+	+	+
Summarize the patient case				+[a]
Planning		+		+
Foresee a technical success		+		+
Preparation of tools			+	+
Imaging				
Handling radiographic imaging equipment	+	+	+	+
Quality of images		+		+
Visualizing relevant structures		+		+
Centering of the picture with overview of manipulated tools during fluoroscopy				+[a]
Angling of the C-arm				+[a]
Radiation discipline	+	+	+	+
Angiography	+	+	+	+
Use of contrast fluid				+[a]
Technical skills				
Tools selection	+	+	+	+
Tools manipulation/Instrument handling	+			+
-Guide wire/Catheter	+	+	+	+
-Stent/Balloon	+	+	+	+
Awareness of guide wire position outside the patient				+[a]
Gross motor movements				+[a]
Respect for tissue and stenosis	+	+		+
Awareness and respect for the puncture site				+[a]
Evaluation of stenosis		+		+
Pre-dilatation of stenosis				+[a]
Hand-eye coordination on manipulating tools during fluoroscopy				+[a]
Bimanual coordination during stent deployment due to opposite forces directed at keeping the stent in position				+[a]
Correction of stent position during deployment				+[a]
Vascular anatomy	+	+		+
Safe removal of tools				+[a]
Obtain hemostasis		+	+	+
Aseptic technique	+			
Procedure				
Knowledge of procedure	+	+		+
Sequencing of procedure				+[a]
Time and motion	+			
Flow of operation	+			
-Ability to complete the case	+			
-Need for verbal prompts	+			
-Attending takeover	+			
Adaptation and use of alternative plan		+		+
Choice of treatment according to angiography and the patient status		+		+
Knowledge of complications		+		+

(*continued on next page*)

Table 2 (*continued*)

Themes and sub-themes	Literature characterising endovascular (EV) competence			The study of clinicians with different levels of EV experience ($N = 7$)
	Global rating scales (1,6,9,12,15,23)	Clinical competence statements (25,29-32)	Task analysis (33,34)	
Treatment of complications		+		+
Knowledge of pharmacological agents necessary during the procedure		+		
Communication				
Discuss results and recommendations with the patient		+		
Respect for patient pain				+[a]
Use of assistant				+[a]
Post-procedure				
Post-planning		+		+
Immediate plan until hospital discharge				+[a]
Long-term follow-up				+[a]
Overall performance				
Quality of final product	+			
Overall performance	+			

[a] Additional data contribution from the study of clinicians.

Literature review characterising EV competence

GRSs applied in empirical studies of EV procedures

Twenty-seven articles were retrieved; four articles with a GRS were included.[1,6,9,15] In addition, two articles were included from a cross-referenced search.[12,23] The GRSs mainly informed on technical issues reflecting the ability of selecting and handling tools appropriately. A few studies addressed imaging[6,15] and angiography[9] as well as knowledge of vascular anatomy[9] and procedural knowledge.[6,12,15] Generally influenced by the objective structured assessment of technical skill (OSATS) scale,[14] these articles addressed procedural aspects such as time and motion, flow of operation and overall performance.

Clinical competence statements from EV scientific societies

Twenty-nine articles were retrieved; two articles with clinical competence statements from North American scientific societies were included.[29,30] In addition, three articles were included from a cross-referenced search.[25,31,32] The additional aspects included pre-procedural planning based on a review of the patient's clinical status and the interpretation of a physical examination as well as pre-operative diagnostic imaging methods (e.g., ultrasound (US), magnetic resonance imaging (MRI) and computed tomography (CT)). Moreover, an ability to foresee a technical success and the prediction of complications, knowledge of radiation physics and the discipline of radiation, an ability to generate images of good quality and to evaluate the images and assess the occlusive lesions were needed. Furthermore, a foreknowledge of complications and appropriate treatment thereof was necessary, as well as knowledge of pharmacological agents required during the procedure. Finally, regarding the technical competencies, the reports stated an overall ability of handling instruments safely without providing a detailed description of the various techniques to be assimilated.

Task analysis of EV procedures of arterial angioplasty

Six articles were retrieved; one article concerning arterial angioplasty was included.[33] In addition, one article was included from a cross-referenced search.[34] These papers informed on phases of the entire procedure from start-up to wrap-up. Finally, preparation of tools was added to the list, as this seems to be of significance to overall performance accounting for 9% up to 17% of the total procedure time.[34]

Clinicians' perceptions of developing endovascular expertise

Data were collected from four experts in Interventional Radiology (experience >10 years), and three EV trainees (median experience 4 months), from the Departments of Radiology and Vascular Surgery, Rigshospitalet; and the Department of Radiology, Gentofte Hospital.

Examples from the process of analysing clinicians' perceptions with identification of themes and sub-themes are presented in Table 3.

The clinicians contributed with an additional 17 sub-themes to the list in Table 2, resulting in a total number of 47 sub-themes characterising EV competence. Several sub-themes were closely inter-related.

An example from the theme of imaging was expert reports on the appropriate use of fluoroscopy with correct angling of the C-arm (Fig. 2). Clinicians specified the theme of technical skills regarding operator awareness of guide

Table 3 Examples of clinicians' perceptions on developing endovascular expertise with identification and classification of themes and sub-themes for coding the data.

Classification of themes and sub-themes for coding data	Perceptions on developing endovascular expertise	Clinicians
Pre-planning	*"Novices need to learn planning of procedures and think one step ahead. Always carry a plan B."*	ID 1 Expert
Imaging - Overview of manipulated tools	*"Novices typically struggle with centering of the fluoroscopic picture during manipulation of tools without focusing on all relevant parts of tools. Hence, flipping back of tools in aorta easily occurs."*	ID 3 Expert
Technical skills - Keeping stent in position during deployment	*"I had difficulties learning how to deploy a stent safely keeping it positioned. It was difficult to learn how to correct the stent position if it moved during deployment."*	ID 6 Trainee (Radiology)
Technical skills - Hand-eye coordination during fluoroscopy - Focus of visual attention	*"The endovascular technique implies manipulation of tools while focusing on the fluoroscopic monitor. The technique differs from open surgery and you have to learn to abstract from looking down on your hands."*	ID 7 Trainee (Vasc. Surgery)
Procedure - Adaptation of strategy	*"In the beginning I just went on trying to pass an anatomically difficult structure without thinking of alternative tools to use even though I was aware of other tools' properties."*	ID 5 Trainee (Radiology)
Procedure - Choice of treatment	*"During EV procedures it is imperative to decide whether a patient needs intervention or not, and what treatment benefits the specific patient best that is endovascular, open surgery or best medical."*	ID 2 Expert
Communication - Respect for patient pain	*"A good communication with the patient on table and respect for any patient pain is very important for endovascular novices to succeed."*	ID 4 Expert

wire position outside the patient, awareness and respect for the puncture site and control of gross motor movements. Correct sequencing of a procedure without omitting important steps for operator convenience, as reported by a trainee, was an example of a procedural sub-theme. Use of assistance from staff members in the angiosuite was reported at premium importance for EV novices to succeed, thus added to the theme of communication. Experts informed on the necessity of acquiring post-planning skills with operators stating an immediate plan for the patient and a plan for long-term follow-up.

The 'novel' assessment form

A novel global rating scale SAVE (Structured Assessment of endoVascular Expertise) (Table 4) was synthesised from the themes and sub-themes in Table 2. The assessment instrument includes 29 items, grouped in seven categories, and a single overall score.

Inspired by a report on change of selective focus of visual attention during development of expertise[35] and clinicians' reports in this study, we divided the overall aspect of technical skills on instrument handling into two separate categories: an external technique (Category 3) and an internal technique during fluoroscopy (Category 4). EV operators continuously alter their visual focus and actions between an external area (with preparation, exchanging, flushing, wetting of tools and awareness of the puncture site) and focus on the fluoroscopic monitor (internal) while delicately manipulating the tools.

Knowledge of complications was positioned under the first category of pre-planning (item 1.3) and knowledge of treatment options under the category of post-planning (item 7.3).

The objective parameters of procedure time, fluoroscopy time, number of images and contrast volume used were added to the scale format without directly contributing to the performance score. Even though these metrics are questionably valid in simulated procedures, the clinical relevance might be significant for assessing later stages of learning.[36]

Discussion

In contrast to other available rating scales[1,6,9,12,15,23] the novel SAVE scale addresses several aspects of procedural non-technical skills. Pre-procedural planning is an essential first step of EV procedures[37] and relates well to theories on development of expertise in which a forethought phase of task analysis, goal setting and strategic planning characterises expert performance.[38] The effect of predicting procedural challenges was confirmed in a recent trial that significantly reduced morbidity (11–7%, $P < 0.001$) and mortality (1.5–0.8%, $P = 0.003$) in surgical procedures.[39]

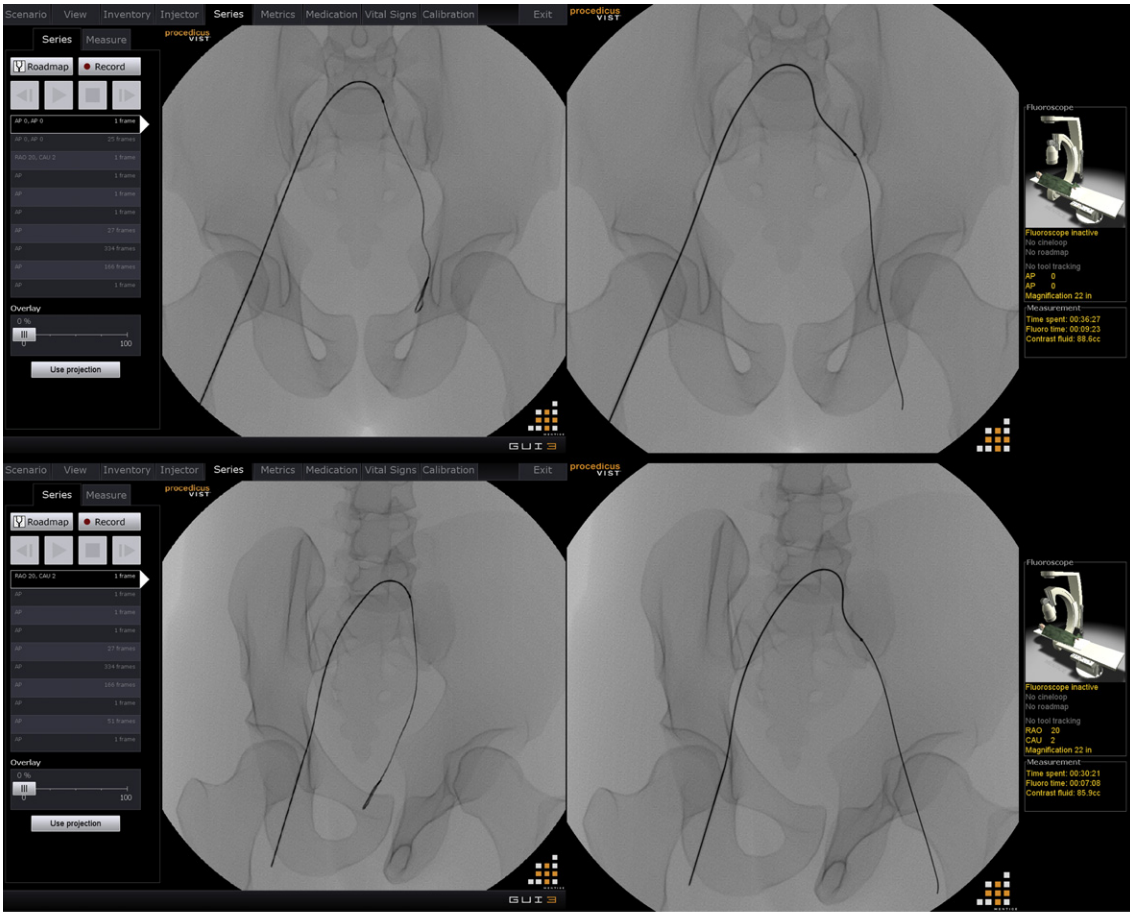

Figure 2 Fluoroscopic presentation of guide wire and catheter position in a case of contralateral iliac-artery stenting by the VIST simulator. Position of the C-arm visualized at utmost right. Images at top: anterior—posterior (AP) view. Images at bottom: 20° right anterior oblique (RAO) view. Images at left: cannulation of the left internal iliac artery (IIA). Images at right: cannulation of the left external iliac artery (EIA). Notice on the top images the small difference in the presentation of guide wire position between the IIA and the EIA due to superimposition. Appropriate angling of the C-arm clearly separates the position of the IIA and the EIA (images at bottom).

Other examples of non-technical cognitive aspects are the ability to recognise and adapt to unforeseen circumstances during task execution. Theories of expertise and self-regulatory learning strategies support these adaptive abilities as central for developing procedural expertise.[38] This issue is inter-related with the issue of flow of operation as addressed in other GRSs.[6,12,23] However, these scales focussed on dexterity skills as a single aspect of flow of operation. A reduced flow of operation can have several causes beside inappropriate manipulative skills on tools for example, inappropriate use of angiographic equipment (Fig. 2). Hence, such detailed deconstruction of the construct is central for applying effective instructional strategies.[40]

Moreover, our study shed light on other procedural non-technical aspects of EV expertise such as clinical reasoning and decision making. Choice of appropriate treatment requires knowledge of various treatment outcomes as stated in scientific societies' guidelines,[41] and single-centre experience, set in relation to expected benefit for the patient according to angiographic findings, co-morbidity, age, compliance, etc. Procedural decision making was taught and assessed with success in other surgical areas[42] and we suggest implementation into the basic EV curriculum.

Assessing communication skills with the patient on table during EV procedures and respecting any patient pain have gained no attention in prior GRSs.[1,6,9,12,15,23] This is somehow surprising as the vast majority of EV procedures are carried out on conscious patients and patient pain can be a sign of imminent complications. Experiences from teaching inter-personal skills within simulated EV procedures has been reported[43] and a recent review addressed the importance of this issue.[26] Similarly, we found effective use of assistance from staff members which was crucial for novices to succeed in EV procedures, as was present in the original OSATS scale by Martin et al.[14] but left out in all the modified versions designed for the EV field.[1,6,9,12,15,23]

Methodology for characterising development of expertise

Application of acknowledged research methodology aiming at deconstructing EV competence into its key components

Table 4 The global rating scale SAVE *(Structured Assessment of endoVascular Expertise)* includes 29 items, grouped in 7 categories, and a single overall score.

Structured Assessment of endoVascular Expertise - SAVE					
Study: **ID no.:** **Date:** **Assessor:**					
0=Poor 1=Inadequate 2=Good 3=Very good 4=Excellent	**0**	**1**	**2**	**3**	**4**
1. Procedure plan and preparation					
1.1 Can summarize the patient case briefly and clearly					
1.2 Can state a clear and relevant plan for the procedure					
1.3 Can briefly predict technical challenges and potential complications					
1.4 Demonstrates appropriate preparation of the assistant table					
2. Imaging					
2.1 Demonstrates appropriate handling of the C-arm and the patient table					
2.2 Can generate angiographic images in a good quality of relevant structures					
2.3 Demonstrates correct use of fluoroscopy with a good overview of manipulated tools					
2.4 Demonstrates appropriate use of contrast fluid					
3. Tools - External technique					
3.1 Can select the appropriate tools					
3.2 Demonstrates correct preparation and safe handling of guide wires, catheters, and sheaths with economy of gross motor movements					
3.3 Demonstrates correct preparation and safe handling of stents and dilatation catheters with economy of gross motor movements					
3.4 Demonstrates awareness and respect for the puncture site					
4. Endovascular - Internal technique during fluoroscopy					
4.1 Can name the relevant anatomical structures during the procedure					
4.2 Can evaluate the angiographic images and the stenosis properly					
4.3 Can specify the 'common rules' for treatment of the specific vascular structure/bed					
4.4 Demonstrates a stabile, precise, and well-coordinated internal technique handling guide wires, catheters, and sheaths with economy of fine motor movements					
4.5 Demonstrates awareness of guide wire position					
4.6 Demonstrates a stabile, precise and well-coordinated internal technique applying appropriate forces on stents and dilatation catheters					
4.7 Demonstrates clear respect for tissue and the stenosis thereby minimizing complications					
4.8 Removes the tools safely					
5. Procedure					
5.1 Demonstrates correct sequencing of the procedure and administers medicine					
5.2 Demonstrates flow of operation without need for verbal prompts					
5.3 Can recognize and adapt to unforeseen circumstances using an alternative plan					
5.4 Chooses the treatment correctly according to angiography and the patient status					
6. Communication and use of assistant					
6.1 Can inform the patient correctly during the procedure					
6.2 Communicates and activates assistants appropriately during the procedure					
7. Post-planning and treatment of complications					
7.1 Can specify the immediate post-treatment plan prior to hospital discharge					
7.2 Can specify the long-term follow-up plan after hospital discharge					
7.3 Can specify the treatment of possible technical per-operative complications					
8. Overall level of endovascular expertise					
Procedure time = min Fluoroscopy time = min No. of images= Contrast vol. = ml					

was suggested by transatlantic EV societies.[40] Available GRSs were constructed from expert opinions (Table 1) without informing on applied methods. By contrast, we sampled data from a literature review and supplemented with data from an experimental study with the method of retrospective verbalisation.[27] Inclusion of trainees brought additional information compared with expert statements. An example was a trainee reporting on intended 'omission of procedural steps' for operator convenience, consequentially with 'incorrect sequencing' of the procedure. These items accounted for the majority of procedural errors in a study on laparoscopic surgery alongside the use of excessive force on instruments.[17]

Limitations

Simulation setting

Even though the participants were pre-instructed to abstract from the simulation setting during retrospective verbalisations, this milieu definitely limits performance as current simulators lack fidelity.[40] Missing features are a physical replication of the C-arm and an adjustable patient table. Furthermore, virtual reality (VR) simulators cannot replicate the thrombogenic (wet) milieu of a clinical angiosuite; thus, crucial issues such as wetting guide wires, flushing catheters and administration of medicine becomes redundant in the VR lab. These features are reproducible in an animal lab[15] as well as procedural complications, for example, vessel rupture. Hence, generalisation of the results in this study should be taken with precaution regarding clinical applicability.

Sample size

We acknowledge the study can be criticised for a small sample size of clinicians ($N = 7$). However, we found inclusion of the last participants not bringing substantial novel data and regarded sampling to redundancy[21] (i.e., saturation) was achieved without threatening validity.

The iliac procedure

The iliac-artery stenting procedure is fairly easy. Characterising the later stages of developing EV expertise probably has to include more complex procedures such as renal artery stenting[5], (RAS) or carotid artery stenting[8,12] (CAS). For example, a monorail technique and knowledge of various pharmacological agents and their procedural usage are issues of relevance in these tasks. However, the categories and items in the SAVE scale are rather general and probably also apply to more complex EV procedures.

Perspectives

The SAVE scale provides an opportunity for capturing the essence of developing EV expertise and further research should aim at studying this scale for validity and reliability in simulation and clinical settings as well as for the study of transfer of skills from simulated environments to real patients.[6,44]

The comprehensive characterisation of EV competence with detailed assessment subsequently serves several other purposes.[22]

Efficient learning requires detailed individualised formative feedback to the trainee, for example, as with the method of deliberate practise.[45] The SAVE scale, comprising 29 items, provides supervisors with such a tool that generates a profile of competence and facilitates individualised feedback in depth. It was found that novice learners of complex motor skills might improve early learning effectiveness by focusing practise on performance 'process' goals instead of performance 'outcome' goals.[36] The 29 items might represent process goals upon developing EV expertise.

In addition, the results from this study might aid stakeholders in designing EV curricula and ensuring comprehensiveness[46] as well as for purposes of testing such as credentialing or board certification.[24] Thus, we suggest the non-technical skills addressed in this study be evaluated.

Conclusion

For capturing the essence of developing endovascular expertise, we constructed a novel GRS (SAVE) consisting of 29 items. In addition to basic knowledge and mere technical skills, endovascular expertise comprises aspects of complex cognitive skills. We suggest that these aspects be incorporated with the endovascular curriculum and assessed upon credentialing.

Conflict of Interest

Lars Lönn MD, PhD, is a consultant at Mentice AB.

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