

A Pilot Study of Video-motion Analysis in Endovascular Surgery: Development of Real-time Discriminatory Skill Metrics[☆]

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WHAT THIS PAPER ADDS

In an era of rapid advancement both in endovascular technique and technology, truly objective assessment of competence for the purpose of maintaining the highest standards in vascular care has become essential. Existing methods of assessment involve simulator-based metrics as well as qualitative scoring systems in the live-case setting. The latter often require time-consuming expert-assessments. This study is, to the author's knowledge, the first to describe semi-automated motion tracking of endovascular tools, using video fluoroscopy sequences as a medium for assessment of skill.

Objectives: Accurate assessment and credentialing of physicians is essential.

Objective motion analysis of guide-wire/catheter manipulation to assess proficiency during endovascular interventions remains unexplored. This study aims to assess its feasibility and its role in evaluation of technical ability.

Materials and methods: A semi-automated catheter-tracking software was developed which allows for frame-by-frame motion analysis of fluoroscopic videos and calculation 2D catheter tip path-length. 21 interventionalists (6 cardiologists, 8 interventional radiologists, 7 vascular surgeons; 14/21 had performed >500 endovascular procedures) performed an identical carotid artery stenting procedure (CAS) on a VIST simulator (Mentice, Gothenburg, Sweden). Operators were sub-divided into four categories according to CAS experience: 6 inexperienced (0 CAS-group A), 3 low-volume (1–20 CAS-group B), 5 moderate-volume (21–50 CAS-group C) and 7 high-volume (>50 CAS-group D) CAS experience. Total PL was calculated for each case and comparisons made between groups. PL was correlated with: quantitative, simulator-derived metrics and qualitative performance scores (generic and procedure-specific) derived from post-hoc video analysis by three blinded observers.

Results: Group D used 5160.3 (inter-quartile range- IQR 4046.4–7142.9) pixels of movement, compared to 6856.7 (5914.4–8106.9) for group A ($p = 0.046$); 10,905.1 (7851.1–14,381.5) for group B ($p = 0.017$); and 9482.6 (8663.5–13,847.6) for group C ($p = 0.003$). Statistically significant inverse correlations were seen between total PL and qualitative performance scores ($\rho = -0.519$ for generic ($p = 0.027$) $\rho = -0.567$ for procedure-specific ($p = 0.014$) scores). PL did not correlate with any of the simulator-derived metrics (errors, contrast volume, total procedure and fluoroscopy times, cine-loops used).

Conclusion: Endovascular instrument video motion analysis is feasible and may represent a valuable tool for the objective assessment of endovascular skill.

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[☆] The data in this paper has also been reported in part in a previous paper using the same cohort of participants (Van Herzele et al., J Vasc Surg 2007;46:855–63). The originality of this article lies with the presentation of a novel method of endovascular skill assessment.

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INTRODUCTION

In an era of reduced working hours and increased patient demands it has become necessary not only to offer additional training opportunities outside the remit of the traditional surgical apprenticeship model, but also to provide a means by which surgical performance can be assessed. Simulation offers the opportunity to train in an educationally-oriented environment without subjecting patients to increased risk, whilst also providing the opportunity for on-going feedback and assessment outside the demands of clinical case workload. Most high-fidelity simulators, such as the VIST (Mentice, Gothenburg, Sweden), provide instantaneous and automated feedback on metrics such as total procedure and fluoroscopy times and simulator-recorded errors. The metrics recorded by a variety of simulators have demonstrated good construct validity in terms of endovascular training and experience.^{1–3}

However, such metrics can only be regarded as crude surrogate markers of technical skill and the overall quality of endovascular performance. Several qualitative rating scales have been developed in an attempt to assess endovascular performance, for example the generic endovascular rating scale⁴ and the procedure-specific rating scale.² Many of these are derived from the generic Objective Structured Assessment of Technical Skills (OSATS)⁵ and incorporate domains such as knowledge and handling of endovascular material, pre-planning, clinical decision making, as well as technical aspects such as catheter/wire manipulation skills. Whilst many of these qualitative scoring systems demonstrate construct validity and good inter-observer reliability, they require time-consuming, video-based post-hoc analyses by at least two experts. In addition, assigning numerical values to qualitative statements exposes these assessments to a degree of subjectivity.

Motion analysis as a tool to evaluate skill is currently unexplored in the field of endovascular surgery. The technology does exist to track hand movements during open and laparoscopic surgery.⁶ We hypothesise that surgical efficiency can be measured by tracking the distal-most tip of the surgical instrument, and in the case endovascular intervention; the tip of the guide-wire or catheter. A reduction of total movement (or path-length) required to successfully complete an endovascular task, may represent a reliable measure of skill. The primary objective of this study was therefore to study a novel endovascular metric — guide-wire/catheter tip path-length (PL), in order to determine whether this constitutes an objective and sensitive discriminator of endovascular skill. The secondary objective was to correlate PL with existing simulator-derived metrics and qualitative rating scales.

METHOD

Subjects

Twenty-one endovascular physicians participated in this study. Each had performed at least 100 general endovascular cases as primary operator. This number was arbitrarily

selected to realistically reflect the minimum endovascular experience required for carotid artery stenting (CAS) training. Six interventional cardiologists (IC), eight interventional radiologists (IR) and seven vascular surgeons (VS) participated. 66% had performed at least 500 endovascular interventions as primary operator. They were sub-divided into four categories according to CAS experience: inexperienced (0 CAS cases performed, 3 IR and 3 IC participants), low-volume (1–20 CAS cases performed, 2 VS and 1 IC participants), moderate-volume (21–50 CAS cases performed, 1 VS, 2 IR and 2 IC participants) and high-volume interventionalists (>50 CAS cases performed, 4 VS and 3 IR participants). The moderate- and high-volume groups had performed only 1 and 2 previous virtual-reality simulations, respectively. No one in the inexperienced or low-volume groups had previous VIST experience.

The vascular intervention simulation trainer (VIST) simulator

The VIST simulator is a high fidelity endovascular simulator which consists of a personal computer-based software interface (Procedicus, Mentice AB, Gothenburg, Sweden) and two monitors linked to an interface device that allow the user to insert and manipulate wires, catheters, balloons, stents and other endovascular tools. The subject begins the procedure by selecting specific tools that are inserted into the user interface, which represents the virtual patient. A fluoroscopic image activated by a foot pedal is displayed together with the virtual tools. Separate controllers for simulated stent deployment, balloon inflation, and contrast material injection are provided. User interface functions include fluoroscopic C-arm positioning, table movements, road mapping and cine-loop recording.

Task performed

All subjects received an initial didactic session on the VIST simulator and were familiarised with the system followed by a practice session of treating an ipsilateral common iliac artery stenosis. Prior to study commencement, available endovascular materials and patient's records demonstrating the target lesion were provided. All participants were asked to treat a proximal right internal carotid artery stenosis (90%) endovascularly in a type 1 aortic arch. The purpose of this study was to validate metrics for endovascular skill assessment rather than knowledge, so for less experienced subjects in CAS a protocol was available explaining the different steps of the CAS procedure. Passive assistance was provided by members of the interventional team comprising of an assistant, radiographer, and a circulating nurse.

Catheter tracking software

A software package was created in C++ and using the OpenCV library (<http://opencv.willowgarage.com/>) to allow video file editing and frame-accurate analysis of fluoroscopic video sequences. A semi-automatic scheme was used to track the motion of the catheter and guide-wire tip

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