The Role of Virtual Reality Simulations in Endovascular Procedure Training

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Abstract

This paper aims to explore the existing literature to identify the current role of virtual reality (VR) simulations in endovascular procedure training. First, we examine the validity of medical simulations for training before we focus on the current use across medical education. Finally, we examine the current use of VR in interventional radiology (IR) training and outline the necessary steps for continued innovations in the field.
Introduction

While the rise of endovascular surgery represents an evolution of traditional open surgery through the marriage of technology and medicine, endovascular training has remained subject to the same apprenticeship structure espoused by William Halsted in his development of the first surgical residency training program at Johns Hopkins in the late 19th century. As elaborated by Desser, the “current medical education framework…is based on the premise that trainees will obtain the necessary expertise by observing and working closely with expert practitioners” (2007). However, more recently, researchers have shown that “within the area of skill acquisition, it is widely accepted that visual observation alone does not lead to proficiency but that repeated deliberate practice is indispensably necessary for skill development, improvement, and maintenance” (Johnson et al. 2011).

While deliberate practice is the preferred method of medical training, its use is stymied in procedural specialties where there is an upper limit to the number of available procedures—this is exacerbated by limitations in duty hours for trainees, the increased incidence of outpatient procedures and the diminishing of “the public’s tolerance for being the ‘guinea pigs’ while trainees gain clinical experience” (Dresser 2007). Whereas in non-procedural specialties these limitations can be overcome through the use of standardized patients, “the use of live volunteers for hands-on training in surgical and radiologic procedures (especially those that involve the placement of implants) is impossible” (Bott et al. 2011).

To address these concerns, “the American College of Surgeons developed support for the use of simulation-based training in a variety of settings,” particularly because “the use of well-designed simulations permits the learner to be trained in a controlled environment without compromising safety and patient outcomes, allows exposure to challenging and complex events
in a controlled setting, and allows practice until perfection” (Schirmer et al. 2013). This parallels the field of aviation, where many of the same concerns come into play and “teamwork training with simulation has been instrumental in reducing errors” (Schirmer et al. 2013). Just as pilots practice extensively on simulators before ever entering the cockpit of a plane, “simulation exercises provide medical trainees with hands-on experience and have the potential to accelerate learning dramatically, particularly early in training, without exposing patients to any risk” (Desser 2007).

**Validity of Simulators in Medical Training**

The overall usefulness of simulations in medical training is important to confirm before investment into the development of high-fidelity simulators and their integration into curricula—high costs and the possibility of insufficient or detrimental training necessitate an accurate understanding of the benefits and risks of their implementation. In a systematic review by Issenberg et al. cited by Gould, 109 published studies were examined to determine “whether medical simulation facilitates learning” (2007). Gould summarizes the findings as follows:

“[The] best available evidence did show a benefit for simulation when the following conditions are met: (a) educational feedback is provided, (b) learners are given the opportunity for repetitive practice, (c) tasks range in difficulty, and (d) the exercises based on the simulation are integrated into the curriculum.” (2007)

Generally, “learning by playing seems to be a solid method to gain better appropriation for the learner…[they] seem to better enable the learner to feel immersed, to improve their confidence, and to enhance their clinical skills” (Gautier et al. 2016).
Focusing on software-based virtual reality (VR) simulators, more recent studies have shown mixed results concerning their efficacy. For example, research done on an ultrasound simulator “showed that the simulator improved residents’ abdominal and pelvic scanning technique, as well as their self-assessment scores,” prompting the researchers to “[conclude] that the simulator was useful for both training and the evaluation of residents’ performance” (Desser 2007). Similarly, simulation software aimed at teaching transvaginal ultrasound techniques to obstetrical and gynecological residents “[suggested] the superiority of a single virtual reality simulation training session over a single session of theoretical teaching of the same duration” in unexperienced operators” (Chao et al. 2015). On the other hand, a comparison of “laparoscopic surgery performance on real-life pigs for a group of surgical residents who received training on a VR surgical simulator with a control group that did not receive any simulator training…did not provide evidence for the training effectiveness of the simulator, with no significant performance differences between the two groups” (Johnson et al. 2011).

Overarching considerations relevant to the development of include “an assessment of the quality, comprehensiveness, usability, and acceptability of the contents to users” as well as a determination as to “whether the result of its use is an improvement in learning beyond that achieved with traditional training or other computer-based training systems” (Bott et al. 2011). Because of this, the integration of VR simulations is sparse in current medical training despite confirmation of their validity in teaching. This is also in part due to the lack of totality in teaching all aspects of procedural care—for example, “existing surgical simulators, both part task and procedural, are primarily focused on the development of psychomotor skills” and “offer little training in cognitive skills associated with higher level mental functions related to workload
management, planning, communication, decision-making and problem-solving” (Sankaranarayanan et al. 2015).

**The Adoption of Virtual Reality Simulations in Interventional Radiology Training**

Use of VR simulations in endovascular training for interventional radiologists is an area that is rapidly expanding following studies that “have demonstrated the efficacy and validity of endovascular simulators” and prompting the European Virtual Reality Endovascular Research Team to “systematically [study] different components of the use of endovascular simulators and [find] them valid and useful if used within a structured curriculum” (Schirmer et al. 2013). Their use in endovascular training has also been encouraged by the FDA, with a recent “decision to approve one manufacturer’s carotid stent, contingent on the company’s devising a training system that did not put patients at risk” that “set a precedent and provided a major impetus for the development of endovascular simulators” (Desser 2007).

Trials specific to endovascular procedures have shown positive results similar to those seen in ultrasound and laparoscopic procedure training—an examination of commercial VR simulators such as virtX showed “a positive short-term effect of simulation-based training in radiology, but the long-term effects of such training on knowledge internalization are as yet unknown” (Bott et al. 2011). Similarly, a randomized trial was performed by Chaer et al. “examining transfer of VR endovascular training (iliofemoral angioplasty) to the human model”—results showed “significantly improved performance that was rated with use of a procedure-specific checklist and a global rating scale” (Ahmed et al. 2010). This also informs the necessity of expert involvement in the development of the simulations—the development of an accurate simulations that “[permits] valid modeling and assessment of tasks while reducing the
risk of training inappropriate or incorrect skills…[needs] detailed information about what it is that the clinician is actually doing during a real procedure” (Gould 2007).

Once the direction of the simulation is determined by consultation with a subject-matter expert, the simulation should focus on realism to add validity—as such, “accurate models of individual variations in anatomy and pathology should be available, and dynamic models of vessel wall behavior are needed” (Dankelman et al. 2004). However, certain technical aspects of model implementation are “still very difficult to achieve in VR,” such as “realistic simulation of the interaction of the instrument with the vascular wall and rendering of all kinds of pathological conditions” (Dankelman et al. 2004). A high-fidelity simulation is therefore still plagued by technical difficulties regardless of validity and usefulness, and the development of such “a full-
scale interventional simulator is very costly, and its effectiveness will be difficult to evaluate” (Dankelman et al. 2004).

While current implementations are plagued by “reduced tactile feedback (haptics), lack of case-by-case variety, and lack of exact replication of fine motor skills,” VR simulations can supplement current training methods by providing “an early endovascular training experience…with the advantage of objective assessment of performance” (Ahmed et al. 2010). Improvements in processing power, haptics and the ubiquitous nature of commercial VR platforms provided by the Oculus Rift and Microsoft Hololens will only accelerate the development and integration of high-fidelity simulations in the training of interventional radiologists.
References


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