Significant intraoperative bleeding can be a stress-inducing event for neurosurgeons. Most neurosurgeons will undoubtedly recall dealing with a ruptured aneurysm or heavily bleeding tumor at some point in their training or career. High-volume blood loss can be particularly stressful, and this stress can impact fine motor control, increase tremor, and impair judgment as the surgeon attempts to deal with intraoperative events. The risk to the patient involves both the actual blood loss and associated alterations in physiology such as hypotension. Moreover, as the surgeon attempts to control bleeding, surrounding normal tissues are at an increased risk of inadvertent injury because of impaired visualization and impaired motor performance.

In this article, Bajunaid et al. attempted to quantify the effects of stress on psychomotor performance when uncontrolled “bleeding” occurred in a virtual reality simulated tumor resection task. The task was performed by operators with various levels of expertise, including attending neurosurgeons, residents, and medical students. The operators did not have prior knowledge of the event or what would be measured in terms of study outcomes. The study demonstrated differences in how the intraoperative bleeding event was handled. The more experienced neurosurgeons achieved a greater degree of tumor resection despite the bleeding and demonstrated a higher level of the coordinated use of a suction device in the nondominant hand and an ultrasonic aspiration tool in the dominant hand to control bleeding during the bleeding stress scenario. Overall, the operative efficiency of the attending neurosurgeons, while reduced during the stress episode, was still higher than the baseline performance of resident surgeons; this finding is consistent with a graded development of operative skills during and after residency training.

While the number of participants was relatively small, the virtual tumor resection task had limited complexity, and there are other limitations, this study does contribute a unique assessment of the immediate impact of an unexpected complication on the surgeon in a virtual reality simulation. A valuable outgrowth of this type of work could be validated strategies to enhance surgeon preparation for rare intraoperative events and to improve complication avoidance. Documented resident preparation in handling a number of virtual reality intraoperative complication scenarios could become a staple of our training programs. Lastly, I hope that future virtual reality scenarios created by the authors will also assess the impact of an acute intraoperative stressor requiring simultaneous motor attention on any required medical decision making (for example, instructions to the anesthesiologist).

References

Disclosures
The author reports no conflict.

Response
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We thank Dr. Carter for his insightful comments. Severe bleeding can occur in a variety of neurosurgical procedures but is usually brought under control by direct pres-
sure using patties, coagulation, and/or clipping of vessel structures and the use of hemostatic techniques. The removal of patties, like the initial event, can be associated with hemorrhage resulting in hypotension, bradycardia, and cardiac arrest in the patient. Our study explored how bimanual psychomotor performance in an acutely stressful simulated tumor bleeding scenario followed by the need to immediately perform simulated microsurgery differs between experts and novices. Ericsson and Charness define expert performance as a laboratory technique used to assess expertise in a simulated environment under controlled conditions that should mimic the real task as closely as possible.²

The NeuroTouch virtual reality simulator with haptic feedback was utilized in an attempt to recreate, or mimic, the sense of touch provided by applied forces, vibrations, and motions for the operator, as well as the appropriate instrument sounds and heart beat. These initial scenarios are indeed “limited,” and we are working diligently to develop more realistic scenarios involving a greater number of participants, which could address some of our present shortcomings. For complex neurosurgical scenarios involving lesions adjacent to important motor, sensory, and speech structures, epilepsy scenarios and complex scenarios involving lobectomy need to be available.

Our study confirms that advanced Tier 2 metric technologies focused on the interactions of both hands during simulated neurosurgical procedures are the most useful in differentiating expert from novice performance. However, the development and validation of new metrics such as the force pyramid, which provides a visual and spatial analysis of instrument applied force, and tremor assessment are needed to improve our understanding of surgical skills.¹

A major advantage of simulation is the ability to monitor participant physiological responses including heart rate, respiration rate, heart rate variability, electromyographic activity, peripheral body temperature, and neurological (electroencephalography) responses during procedures such as those performed in our studies, which should provide further insight into the factors influencing operative performance. In the aviation industry, progress in preventing fatalities has involved early warning systems, the application of simulation, and improvements in communication—the “human factor.” The modern neurosurgical operating room has a plethora of patient early warning systems focused on detecting physiological and biochemical problems. In neurosurgery we have yet to implement simulation and adequately focus on the human factor as outlined by Dr. Carter. One can imagine the simulated neurosurgical operating rooms of the future. They would involve libraries of specific simulated operations and complications, which would be utilized for learning. In patient-specific scenarios, the structural lesion is simulated before operation, and potential problems encountered during the procedure could be predicted and a variety of solutions rehearsed by the complete neurosurgical operating team in a dynamic learning environment.

The goal of simulation-based training is to eliminate patient risks associated with skills acquisition, with all learners achieving the desired learning objective in safe environments with the ability to repeat the simulated procedure(s) with appropriate demonstrator and metric feedback. We believe that with the proper simulators, scenarios, validated metrics, proficiency performance benchmarks, curricula, and further efforts to integrate human factor interactions, virtual reality simulation can impart specific bimanual psychomotor, cognitive, and coping skills to residents, helping to shift the goal of surgical training programs from teaching to competence to teaching to expert level. Like any training and/or assessment tool to be implemented, rigorous efforts are necessary to provide evidence for validation and effectiveness over traditional educational methods.

http://thejns.org/doi/abs/10.3171/2015.11.JNS151188

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