Proficiency Performance Benchmarks for Removal of Simulated Brain Tumors Using a Virtual Reality Simulator NeuroTouch

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OBJECTIVE: Assessment of neurosurgical technical skills involved in the resection of cerebral tumors in operative environments is complex. Educators emphasize the need to develop and use objective and meaningful assessment tools that are reliable and valid for assessing trainees' progress in acquiring surgical skills. The purpose of this study was to develop proficiency performance benchmarks for a newly proposed set of objective measures (metrics) of neurosurgical technical skills performance during simulated brain tumor resection using a new virtual reality simulator (NeuroTouch).

DESIGN: Each participant performed the resection of 18 simulated brain tumors of different complexity using the NeuroTouch platform. Surgical performance was computed using Tier 1 and Tier 2 metrics derived from NeuroTouch simulator data consisting of (1) safety metrics, including (a) volume of surrounding simulated normal brain tissue removed, (b) sum of forces utilized, and (c) maximum force applied during tumor resection; (2) quality of operation metric, which involved the percentage of tumor removed; and (3) efficiency metrics, including (a) instrument total tip path lengths and (b) frequency of pedal activation.

SETTING: All studies were conducted in the Neurosurgical Simulation Research Centre, Montreal Neurological Institute and Hospital, McGill University, Montreal, Canada.

PARTICIPANTS: A total of 33 participants were recruited, including 17 experts (board-certified neurosurgeons) and 16 novices (7 senior and 9 junior neurosurgery residents).

RESULTS: The results demonstrated that "expert" neurosurgeons resected less surrounding simulated normal brain tissue and less tumor tissue than residents. These data are consistent with the concept that "experts" focused more on safety of the surgical procedure compared with novices. By analyzing experts' neurosurgical technical skills performance on these different metrics, we were able to establish benchmarks for goal proficiency performance training of neurosurgery residents.

CONCLUSION: This study furthers our understanding of expert neurosurgical performance during the resection of simulated virtual reality tumors and provides neurosurgical trainees with predefined proficiency performance benchmarks designed to maximize the learning of specific surgical technical skills. (J Surg 72:685-696. © 2015 Association of Program Directors in Surgery. Published by Elsevier Inc. All rights reserved.)

KEY WORDS: proficiency performance benchmarks, performance metrics, virtual reality neurosurgical simulation, brain tumor resection, neurosurgical oncology, Neuro Touch

COMPETENCIES: Patient Care, Medical Knowledge, Practice-Based Learning and Improvement

INTRODUCTION

Competency-based education and training has been defined as "an outcomes-based approach to the design, implementation, assessment, and evaluation of medical education programs, using an organizing framework of competencies."[1,2] This approach focuses on having the trainee achieve

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a set of predefined criteria during his/her training to move to the next level of instruction. This education system emphasizes the acquisition of the minimal competency standard of a profession rather than achieving an "expert" level of skills performance.[3,4] Differences commonly exist between competence and performance, and the unavailability of validated tools to evaluate competency acquisition has made it difficult to apply this educational concept to neurosurgical psychomotor performance.[5-8] To address these issues, clear proficiency performance benchmarks need to be developed and made available for neurosurgical operations to improve resident training and surgical psychomotor performance.[9-11] Assessment of surgical skills in the operating room is difficult given variation in operative procedures, diverse standards, differences in the degree residents operate independently, and the occurrence of unpredictable operative events.[11] Given these variables, it is difficult to accurately measure the range of psychomotor skills employed by competent/expert surgeons during brain tumor resections in the operating room, and therefore assessing and imparting these skills to the resident can result in errors that can affect patient safety.[12] Advancement in computer-based technology has created opportunities for implementing new training paradigms such as competency-based education using proficiency performance benchmarks in neurosurgery.[4,12] Virtual reality (VR) simulators are becoming an important means of training and objectively assessing psychomotor performance.[13-15] These systems allow repeated practice of standardized tasks and provide unbiased and objective measurements of performance in safe learning environments with appropriate demonstrator or metrics feedback or both. VR simulation can play a role in the acquisition and improvement of specific neurosurgical skills, and the ImmersiveTouch system has been validated for ventriculostomy.[8,16-18] The Neurosurgical Simulation Research Centre at the Montreal Neurological Institute and Hospital working with the National Research Council (Canada) and other centers has developed and evaluated a computer-based simulator with haptic feedback (NeuroTouch), which provides surgeons and surgical residents the opportunity for deliberate practice and assessment of their level of psychomotor skills competencies.[12,19-23] NeuroTouch is based on finite element mechanics, which can simulate real-time brain deformations, and it uses real-time computing to generate metrics involving multiple assessments of psychomotor performance.[12] This system can simulate brain tumor and normal tissue removal, can generate and measure bleeding, and can provide continuous haptic feedback allowing the operator to have the tactile sensation of the interaction of his/her hand(s) with the simulated instruments and simulated tissues.[19] Surgical performance using the NeuroTouch platform can be assessed using Tier 1 and Tier 2 metrics derived from the NeuroTouch simulator data consisting of (1) safety metrics including (a) volume of surrounding simulated normal brain tissue removed, (b) sum of forces utilized (SFU), and (c) maximum force applied (MFA) during tumor resection; (2) quality of operation metric, which measures the percentage of tumor removed; and (3) efficiency metrics, including (a) instrument total tip path lengths (TTPL) and (b) frequency of pedal activation (FPA).[12] NeuroTouch provides a system that can begin to address the question of proficiency performance benchmark generation using a simulated VR tumor resection for assessment and training of neurosurgical residents.

The 2 purposes of this study were (1) to provide a descriptive analysis of neurosurgical skills performance obtained for neurosurgeons and neurosurgery residents while resecting a series of simulated brain tumors using the NeuroTouch platform and (2) to develop criterion measures for proficiency performance benchmarks on the NeuroTouch simulator for the resection of simulated tumors of various complexities.

METHOD

Before entering the study, each participant was asked to sign a consent form approved by the McGill University Ethics Review Board. A total of 17 neurosurgeons (board certified) from 3 institutions on 2 continents and 16 neurosurgery residents from different postgraduate years (PGY) in the McGill program (9 junior residents, years 1-3, and 7 senior residents, years 4-6) were included in the study. Demographic data collected before participation in the study included age, sex, handedness, level of training, number of meningioma cases operated on, and number of hours of video games or musical instruments played per week.

SIMULATION SCENARIOS

To address the study purposes, a series of 6 simulated brain tumor scenarios developed by our group in a previous pilot study, which involved 18 tumors of the identical shape with different color and stiffness cues, were employed.[12] In scenarios 1 through 3, the 3 tumors within each individual scenario had the same visual color appearance, namely, black tumors (maximum difference between tumor and background, simulated malignant melanoma metastasis) in scenario 1, gliomalike brain tumor appearance derived from an actual patient's malignant glioma image in scenario 2, and similar-to-background tumors (simulated infiltrated white matter) in scenario 3. To outline the range of human brain tumor stiffness, a tactile cue in our scenarios, we assessed multiple samples from 11 different human glial tumors immediately after operative removal and measured their brain tumor stiffness (Young's modulus).[12,19] In each of these first 3 scenarios, the stiffness of the tumors was "soft" (Young's modulus: 3 kPa) in the upper tumor, "medium" (Young's modulus: 9 kPa) in the lower left tumor, and "hard" (Young's modulus: 15 kPa) in the lower