Accelerometer Measurement of Head Movement During Laparoscopic Surgery as a Tool to Evaluate Skill Development of Surgeons

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OBJECTIVE: To detect and measure surgeons' head movement during laparoscopic simulator performance to determine whether expert surgeons have economy of motion in their head movement, including change of direction, compared with intermediate and novice surgeons. We investigated head movement as an objective tool for assessment of laparoscopic surgical skill and its potential use for assessing novice surgeons' progress on the learning curve.

DESIGN: After obtaining institutional review board approval, medical students, urology residents, and attending staff surgeons from an academic institution were recruited. Participants were grouped by level of experience and performed tasks on the Electronic Data Generation for Evaluation laparoscopic simulator. Surgeons wore a commercially available wireless electroencephalogram monitor as a flexible, adjustable, and lightweight headband with 7 sensors—2 forehead sensors, 2 ear sensors, and 3 reference sensors. The headband incorporates a 3-axis accelerometer enabling head movement quantification. A variance analysis was used to compare the average head movement acceleration data between each group.

SETTING: Tulane University Medical Center, New Orleans, LA, an academic medical center and the principal teaching hospital for Tulane University School of Medicine.

PARTICIPANTS: A total of following 19 participants were recruited for the study and stratified by surgical experience into novice ($n = 6$), intermediate ($n = 9$), and expert ($n = 4$) laparoscopy groups: 6 medical students, 9 urology residents (postgraduate years 1 to5), and 4 attending urologists, respectively.

RESULTS: Analysis of the average acceleration rate of head movement showed statistically significant differences among groups on both the vertical axis ($p = 0.006$) and horizontal axis ($p = 0.018$) in the laparoscopic suturing task. This demonstrated the ability to distinguish between experts and novice laparoscopic surgeons. The average acceleration among groups did not demonstrate statistical significance on the vertical axis ($p = 0.078$) and horizontal axis ($p = 0.077$) in the peg transfer task. This may be in response to the ease of the task. The analysis of the forward-backward axis or depth perception also showed no significant differences between groups.

CONCLUSION: Accelerometer-based motion analysis of head movement appears to be a useful tool to evaluate laparoscopic skill development of surgeons in terms of their economy of motion, and it could potentially be used for ergonomic assessment of training in the future, and progression on the learning curve. (J Surg Ed 73:589-594. © 2016 Association of Program Directors in Surgery. Published by Elsevier Inc. All rights reserved.)

KEY WORDS: accelerometer, G-force, motion analysis, ergonomic, surgical skill, simulation, laparoscopy

COMPETENCIES: Medical Knowledge, Practice-Based Learning and Improvement, Systems-Based Practice

INTRODUCTION

The field of urologic laparoscopic surgery has been evolving for more than 30 years. The practice's new operative

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techniques demand the development of new training methods for both assessment and criteria, to assess the progression of the learning curve of residents and fellows. Laparoscopic surgery has a steep learning curve because of trainees' need to manipulate the instruments, listen to staff instruction, recognize the internal anatomy largely without the use of tactile cues, and to avoid injury during dissection. Laparoscopic technique requires great concentration and may induce significant mental stress on surgeons compared with open surgery.[1]

Over the past several decades, researchers have grappled with how to characterize surgical expertise. Several important characteristics have been identified—experts appear to be more focused in work, have a more elaborate visual representation of the task being performed, and are generally engaged in far more deliberate practice of the task than novices.[2] Most extant research, however, has targeted characteristics of expertise rather than metrics that can reliably and objectively distinguish experts from novices.

Traditionally, the tools for subjective assessment included cognitive skills, surgical case logs, and summative evaluations by residency program directors.[3,4] The current training program for minimally invasive surgery techniques includes both bench models and simulations. The skills acquired in the simulation are subsequently transferred to the real environment.[5] The time required to complete a specific task is not necessarily a valid measurement of efficiency and accuracy.[6,7]

A validated questionnaire following surgical performance could contribute to the assessment of a surgeon's performance.[8] Video analysis can define the track of an instrument's movement while not interfering with the procedure.[9] However, the methods reported are not yet standardized, availability is limited, and the process involves complex recording systems and digital image analysis.[4,10] The analysis of movement patterns can be performed with different systems that consist mostly of expensive and specialized equipment.[11]

Ergonomics of laparoscopic surgery are important as a part of patient positioning as well as surgeon optimization of handling instruments for smooth surgical flow. During laparoscopic surgery, urologists early in their learning curve may unknowingly have the monitor position too high, leading to neck strain, or the table height too low, leading to lower back strain.[12] To identify and rectify such problems, biomedical engineers have evaluated these working postures using either direct observation or motion analysis systems.[13-15]

In this research, we assessed head motion analysis during laparoscopic skill tasks on the Electronic Data Generation for Evaluation (EDGE) simulator (SimuLab; Seattle, WA) using an accelerometer from a noninvasive electroencephalogram (EEG) brain monitor headband (MUSE headband, InteraXon, Toronto, Ontario, Canada). The EDGE simulator is the laparoscopic task trainer. Using laparoscopic instruments integrated with 6 sensors, EDGE measures the time for each exercise, path, rotation, and force of the instruments. Results are based on actual haptic feedback, providing quantifiable results to its users. MUSE has accelerometers in 3 axes (x, y, and z), permitting assessment of the quality of head movements in space made by a surgeon while performing a specific task. We used tasks from the Basic Laparoscopic Urologic Surgery (BLUS) curriculum of the American Urological Association.[3] We hypothesized that the novice surgeons make sudden and unnecessary head movements that are registered as wider positive or negative variation in acceleration than the expert surgeons make. There are no similar reports in the literature, nor have others, to our knowledge, used this type of equipment to determine laparoscopic skills. Our study is the first to investigate the objective metric in laparoscopic skill assessment and individual head movement of the surgeon while performing laparoscopic tasks in the surgical simulator.

MATERIALS AND METHODS

With approval from the Institutional Review Board of Tulane University, participants from the Department of Urology and the School of Medicine were recruited for study enrollment. Participants consisted of 3 groups spanning novice, intermediate, and expert level of laparoscopic proficiency based on laparoscopic surgical experience. The novice group ($n = 6$) was composed of medical student volunteers with no prior surgical experience. The intermediate group ($n = 9$) consisted of Urology residents in postgraduate years 2 to 5 of resident training. The expert group ($n = 4$) consisted of the Urology Department's attending physicians with both extensive prior laparoscopic experience and an active practice that includes a focus on minimally invasive surgery.

Overall, the following 2 validated BLUS tasks were used in the participants' accelerometer evaluation: peg transfer and laparoscopic suturing. A study administrator explained and demonstrated each task for each participant before subject testing, whereas an additional administrator explained the MUSE technology and data collection process, and monitored the tasks per participant. Each task was completed on the EDGE laparoscopic simulator.

MUSE is a commercially available wireless EEG monitor, which is worn as a flexible, adjustable, and lightweight headband with the following 7 sensors: 2 forehead sensors, 2 ear sensors, and 3 reference sensors. The headband incorporates a 3-axis accelerometer, enabling quantification of head movements. These features allowed us to conduct our specific study (Fig. 1).

Although participants performed the 2 tasks, we measured accelerometer data using the software development kit provided by MUSE All data were collected using the head sensor and analyzed, after the study was completed.