Objective Surgical Skill Assessment: An Initial Experience by Means of a Sensory Glove Paving the Way to Open Surgery Simulation?

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INTRODUCTION: Simulation and training in surgery are very promising tools for enhancing a surgeon's skill base. Accurate tracking of hand movements can be a strategy for objectively gauging a surgeon's dexterity, although "open" work is much more difficult to evaluate than are laparoscopic tasks. To the authors' knowledge, a system taking into account the movements of each finger joint has never been applied to open surgery simulation. This work intends to make up for this shortcoming and to perform a data analysis of the surgeon's entire gesture.

MATERIALS AND METHODS: The authors developed a sensory glove to measure flexion/extension of each finger joint and wrist movement. Totally 9 experts and 9 novices performed a basic suturing task and their manual performances were recorded within 2 days of measurements. Intraclass correlation coefficients were calculated to assess the ability of the executors to repeat and reproduce the proposed exercise. Wilcoxon signed-rank tests and Mann-Whitney *U*-tests were used to determine whether the 2 groups differ significantly in terms of execution time, repeatability, and reproducibility. Finally, a questionnaire was used to gather operators' subjective opinions.

RESULTS: The experts needed a similar reduced execution time comparing the 2 recording sessions ($p = 0.09$), whereas novices spent more time during the first day ($p = 0.01$). Repeatability did not differ between the 2 days, either for experts ($p = 0.26$) or for novices ($p = 0.86$). The 2 groups performed differently in terms of time ($p < 0.001$), repeatability ($p = 0.01$), and reproducibility ($p < 0.001$) of the same gesture. The system showed an overall moderate repeatability (intraclass correlation coefficient: experts = 0.64; novices = 0.53) and an overall high reproducibility. The questionnaire revealed performers' positive feedback with the glove.

CONCLUSIONS: This initial experience confirmed the validity and reliability of the proposed system in objectively assessing surgeons' technical skill, thus paving the way to a more complex project involving open surgery simulation. (J Surg Ed 72:910-917. © 2015 Association of Program Directors in Surgery. Published by Elsevier Inc. All rights reserved.)

KEY WORDS: skill, assessment, education, open surgery, sensory glove

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

INTRODUCTION

Despite the enormous improvements in effectiveness of surgical treatments in the recent years, the criteria for evaluating the surgical skills of trainees remain mainly subjective. In fact, using observation and experience, expert examiners continue to be the judges of the learners' skills. As the education and training of surgeon still remains a matter of "learning on the job," the apprenticeship learning model is mainly based on observation, imitation, and instructions.

Meanwhile, with the dramatic changes introduced into clinical practice, advances in modern medical and surgical practice have come to be associated with meaningful changes in medical education. Consequently, assessment of learning levels should be based on structured methods and objectivity.[1]

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Because of these innovations, new education methods are being introduced, including basic surgical maneuvers to be practiced by trainees on models and simulators before working in an actual operating room. As Satava[2] predicted, the surgical residents should repeatedly practice surgical procedures until they are perfect before performing surgery on patients. Therefore the "learning curve" (with all the possible mistakes involved) takes place in the laboratory, rather than being inflicted on the patient, leading, of course, to a dramatic improvement in patient safety.[3]

In such a scenario, objective assessment is mandatory, especially as deficiencies in training and performance are difficult to correct without an objective score system. Since 1990s, different systems have been developed to simulate operation procedures and to allow objective assessment without having to bring in expert observers; in this regard, dexterity analysis systems, motion analysis, and virtual reality have all been introduced.[4]

Simulation in surgery, from low-fidelity bench-top models to high-fidelity technologically advanced virtual reality systems,[5,6] has achieved a widespread acceptance, especially in minimally invasive surgery learning.[7] Of late, efforts have been mainly devoted to the laparoscopic operations, for which bidimensional electronic-mediated images and fulcrum-linked motion of the instruments can be easily reproduced for simulation purposes. Despite continual advances in minimally invasive surgery simulators, simulation and objective assessment in open surgery remains a critical component in modern surgical education.[8,9] At present, simulation of open techniques is more challenging and spatially complex, as a comprehensive and immersive environment is needed.[10]

Consequently, assessment in open surgery is still performed via experts' judgement based on observation and verbal feedback or structured assessment,[8] such as the most validated "Objective Structured Assessment of Technical Skill" (OSATS).[11,12] As an alternative, tracking the surgeons' hands, e.g., can greatly improve open surgery simulation and training. Acquisition of surgical hand maneuvers by means of an automated measuring system can provide objective data for assessing real surgical skill in the operating room itself.[9,13]

With the aim of filling the described lack of open surgery skill assessment, we propose an innovative system based on a sensory glove capable of acquiring, storing, and analyzing up to 17 degrees of freedom of the hand in practicing surgical gestures. This is part of a more complex ongoing project where arms and trunk posture and motion can all be measured by means of sensorized garments, leading to quantitative knowledge of the surgeon's "actions." The use of a classification strategy and a virtual reality environment would provide additional data. Overall data gathered from experts' performances can be further implemented, resulting in an average gesture that can be the reference standard for novices and residents.

We present the features related to the initial experience and the validation of an objective assessment tool suitable for open surgery simulation and training that could be easily implemented into standard practice. We focus on evaluating manual performance during surgeons' training in open surgery through measuring his/her hands executing a basic surgical task in a simulated bench operation with real surgical instruments. We compare a group of expert surgeons with respect to a group of novices, our assumption being that skill could lie in the organization of motion[13] and that certain variables, such as execution time and gesture repeatability and reproducibility, can provide significant information for differentiating between surgeons' technical skill levels.

MATERIALS AND METHODS

In order to measure the hand gestures, we developed a sensory glove (Fig. 1) based on acquired experiences for nonsurgical purposes.[14-18] The glove was equipped with 14 flex sensors (by Flexpoint Sensor Systems, Inc., Draper, UT) and a 3-axis accelerometer (ADXL335, by Analog Devices, Inc., Norwood, MA) able to measure the flex/extension capabilities of the finger joints of a human hand, plus the wrist movements. Flex sensors were placed on distal interphalangeal, proximal interphalangeal, and metacarpophalangeal finger joints, and the accelerometer was placed on backside of the hand (Fig. 2). In total 17 signals were collected by means of a custom-made prototype board connected to a computer. The accuracy and repeatability of the measures obtained with this glove are similar to those of others reported in the literature.[19,20]

We realized gloves in 2 sizes (small and medium) so as to best fit the hands of the testers, these consisting of 2 groups of volunteers. There were 9 "experts" (3 men and 6 women, aged 33-35), i.e., surgical residents in their final 3 years of training and with a high level of expertise regarding the task

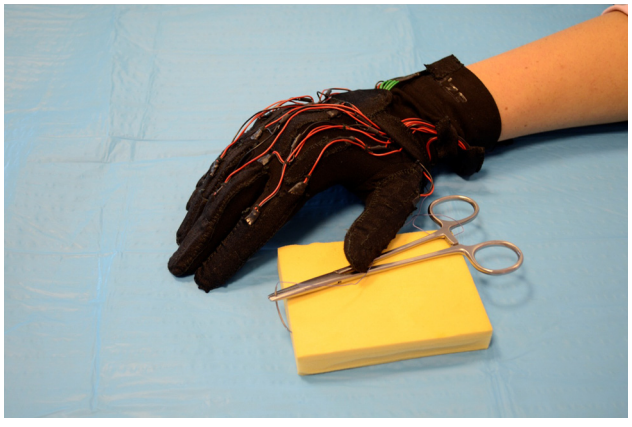

FIGURE 1. The sensory glove was provided with 14 flex sensors and a 3-axis accelerometer able to measure the flex/extension capabilities of the finger joints and the wrist movements.

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