Assessing Microneurosurgical Skill with Medico-Engineering Technology

Kanako Harada[1], Akio Morita[2], Yoshiaki Minakawa[1], Young Min Baek[1], Shigeo Sora[3], Naohiko Sugita[1], Toshikazu Kimura[4], Rokuya Tanikawa[5], Tatsuya Ishikawa[6], Mamoru Mitsuishi[1]

■ OBJECTIVES: **Most methods currently used to assess surgical skill are rather subjective or not adequate for microneurosurgery. Objective and quantitative microneurosurgical skill assessment systems that are capable of accurate measurements are necessary for the further development of microneurosurgery.**

■ METHODS: **Infrared optical motion tracking markers, an inertial measurement unit, and strain gauges were mounted on tweezers to measure many parameters related to instrument manipulation. We then recorded the activity of 23 neurosurgeons. The task completion time, tool path, and needle-gripping force were evaluated for three stitches made in an anastomosis of 0.7-mm artificial blood vessels. Videos of the activity were evaluated by three blinded expert surgeons.**

■ RESULTS: **Surgeons who had recently done many bypass procedures demonstrated better skills. These skilled surgeons performed the anastomosis with in a shorter time, with a shorter tool path, and with a lesser force when extracting the needle.**

■ CONCLUSIONS: **These results show the potential contribution of the system to microsurgical skill assessment. Quantitative and detailed analysis of surgical tasks helps surgeons better understand the key features of the required skills.**

INTRODUCTION

Skills are a very important component of surgery and training. Conventionally, a surgeon's skills have been assessed through visual observation combined with clinical outcomes. To improve the assessment of skills and facilitate training, however, an objective method of measurement is needed.

To date, many surgical skill–assessment methods and systems have been developed (10, 12) and include methods designed to assess microsurgery skills (5). Most of these methods, however, are video-based and rather subjective. Other objective and quantitative assessment methods use devices and simulators, but most of these were designed for laparoscopy; thus, they mainly evaluate psychomotor performance and economy of motion (8). The accuracy of manipulation, however, is the most important skill in microsurgery. Therefore, we need objective and quantitative systems that can accurately measure this aspect to assess microsurgical skill.

This work describes a new microsurgical skill assessment system for neurosurgery with motion-measuring and force-sensing capabilities, without using specific simulator products. The system incorporates infrared optical motion tracking markers, an inertial measurement unit (IMU), and strain gauges mounted on tweezers to record instrument manipulation. Herein, the details of the system and the experiments conducted to assess neurosurgical skill are described, and the findings are compared with conventional and subjective video assessment of the procedures.

MATERIALS AND METHODS

Microsurgery Skill-Assessment System

The skill-assessment system shown in **Figure 1**, which has been described previously with preliminary results (3), was designed to be mobile. This mobility facilitates carrying out skill-assessment experiments at conferences to recruit surgeons with a wide range of clinical experience. Although this type of on-site measurement can be influenced by a surgeon's physical

Key words
- Anastomosis
- Medical engineering
- Microsurgery
- Neurosurgery
- Surgical skill assessment
- Training

Abbreviations and Acronyms
IMU: Inertial measurement unit
VAS: Visual assessment score

From the [1]Department of Mechanical Engineering, The University of Tokyo, Tokyo, Japan; [2]Department of Neurological Surgery, Nippon Medical School, Tokyo, Japan; [3]Department of Neurosurgery, Tokyo Metropolitan Police Hospital, Tokyo, Japan; [4]Department of Neurosurgery, NTT Medical Center Tokyo, Tokyo, Japan; [5]Department of Neurosurgery, Teishinkai Hospital, Sapporo, Japan; and [6]Department of Surgical Neurology, Research Institute for Brain and Blood Vessels-Akita, Akita, Japan

To whom correspondence should be addressed: Akio Morita, M.D., Ph.D.
[E-mail: amor-tky@umin.ac.jp]

Citation: World Neurosurg. (2015) 84, 4:964-971.
http://dx.doi.org/10.1016/j.wneu.2015.05.033

*Journal homepage: **www.WORLDNEUROSURGERY.org***

*Available online: **www.sciencedirect.com***

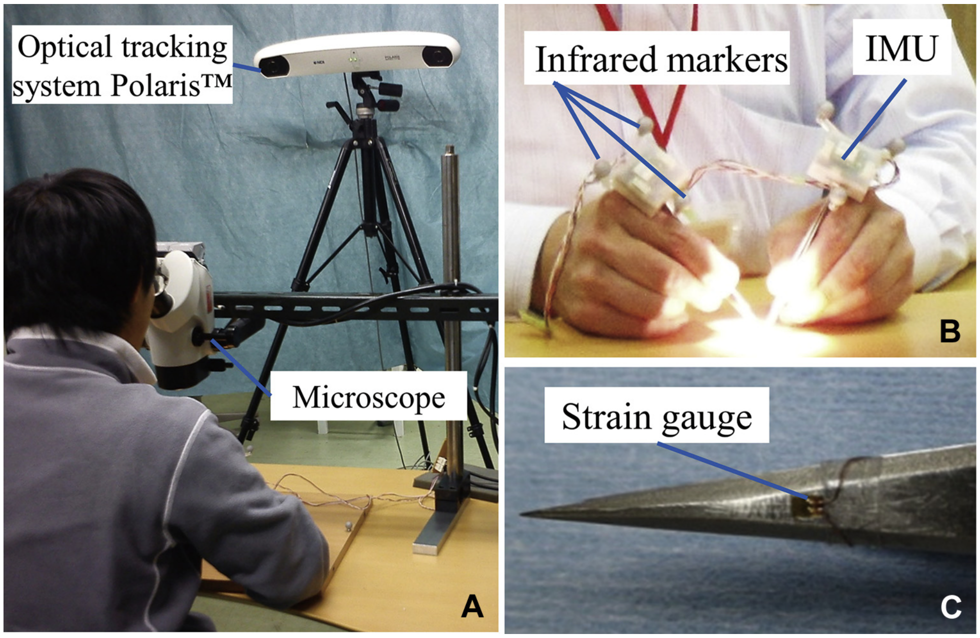

Figure 1. (**A**) The microsurgical skill assessment system comprises a desk with a microscope, an optical position tracking system, and 2 pairs of sensorized tweezers and measurement apparatuses. (**B**) An inertial measurement unit with Bluetooth data transmission capability (IMU-Z) and 3 infrared markers for Polaris are mounted on each pair of watchmakers' tweezers. (**C**) Strain gauges are attached to the tweezers' tips.

condition, motivation, and feelings of tension, we assumed that the differences in ability between unskilled and skilled surgeons would still be evident.

The system comprises a desk with a microscope, 2 pairs of sensorized tweezers, and measurement apparatuses. An IMU unit with Bluetooth data transmission capability (IMU-Z, ZMP Inc., Tokyo, Japan) and 3 infrared markers for the optical position tracking system (Polaris Spectra, Northern Digital, Inc., Waterloo, Ontario, Canada) were mounted on each pair of watchmaker's tweezers (K-1AA, KFI, Japan). Strain gauges (KFR-02N-120-C1-11 N10C2; Kyowa Electronic Instruments Co., Ltd., Tokyo, Japan) also were attached to measure the needle-gripping force, with a maximum error of 1% up to a force of 5 N. The total weight of the sensorized tweezers was 38 g. The sampling frequency of optical motion tracking was 60 Hz, and the theoretical root mean square error was 0.30 mm. The sampling frequency of the IMU unit was 100 Hz, and the theoretical resolution was 0.0096 m/s^2 for acceleration and 0.24 degrees per second for angular velocity. Data from the IMU sensor were not used for the analysis presented in this work.

Experimental Methods

A registration form to be filled in by each subject included sex, age, handedness, clinical specialty, years of clinical experience, years of microsurgical experience, surgical volume for bypass surgery, and surgical volume for the past year. The experimental protocol and data disclosure policy were approved by the ethics committee of the School of Engineering at The University of Tokyo.

The task was an end-to-end anastomosis of 0.7-mm artificial blood vessels (material: silicone; Microvascular Practice Card, Muranaka Medical Instruments Co., Ltd., Tokyo, Japan) with 3 stitches using a 10-0 surgical suture (10V43-10R, Muranaka Medical Instruments Co., Ltd.) cut to 30 mm. Each stitch was secured with 3 knots. The artificial vessels were fixed on the desk with a rotational angle of 30 degrees.

To validate this system, the quantitative data needed to be correlated with a subjective evaluation by experts. Thus, we asked 3 blinded expert surgeons (who is doing the task on the video) (A.M., T.K., R.T.) to assess each participant's skill by reviewing videos recorded during the anastomosis and photos of the anastomosed vessels. We revised the conventional assessment score (formerly called the Medical Assessment Score) defined in the initial article (3) and renamed it the visual assessment score (VAS). To determine the VAS, 10 possible points were given for each of the 3 tasks of the anastomosis (needle placement, suture handling, and knot-tying) performed by each participant, and −3 to 0 penalty points were included for the appearance of the anastomosed artificial blood vessels. In other words, each evaluator could assign a maximum of 30 points to each participant. The scores for all participants given by each evaluator were standardized to compensate for any individual differences among the evaluators. This standardization transformed a variable into a rescaled variable with a mean of zero and a variance of one. Thereafter, the standardized scores from the three evaluators were