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Intraoperative assessment of technical skills on live patients using economy of hand motion: establishing learning curves of surgical competence

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Abstract

BACKGROUND: On surgical simulators, measures of economy of hand motion have been shown to be reliable, valid, and objective measures of technical competence. Our goal was to validate hand-motion analysis (HMA) as an objective measure of surgical skill on real patients.

METHODS: HMA (hand movement frequency, hand travel distance) was evaluated serially on 2 standardized, live patient surgeries (vasectomy, vasectomy reversal) for both a novice and experienced surgeon. HMA parameters were correlated with blinded, case-matched assessments of technical skill using previously validated global rating scales and surgical checklist scores applied to unedited surgical videos. Serial hand-motion data from the novice and experienced surgeon were plotted to establish competency-based learning curves over time.

RESULTS: Intraoperative HMA correlated significantly with case-matched global rating and checklist scores. Meaningful improvements in the number of hand movements and hand travel distance were shown over time for the novice surgeon, but remained stable for the experienced surgeon.

CONCLUSIONS: Intraoperative assessment of economy of hand motion represents a feasible, objective, and valid measure of technical skill and can be used to establish competency-based surgical learning curves.

Live intraoperative assessments of surgical skill represent the ideal standard for the determination of technical competence. Despite significant progress in evaluation of technical competence in the surgical skills training laboratory, intraoperative assessment of technical skill during real surgeries on live patients remains largely unvalidated and subjective.

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Electromagnetic (EM) motion tracking systems have been widely applied in the fields of kinesiology, biomechanics, rehabilitation, and sports medicine to evaluate and follow various clinical entities including joint movements, velocity, and range of motion.[1] More recently, EM technology has been applied to virtual reality environments to aid in the visualization and assessment of complex 3-dimensional spatial relationships.[2] In a novel application of this technology to surgery, researchers at the Imperial College of Science, Technology and Medicine introduced the concept of hand-motion analysis (HMA) using EM technology as a promising method of evaluating surgical competence in the laboratory setting.[3] Small, unobtrusive electromagnetic sensors are placed on the backs of the surgeon's hands and positional data are recorded and analyzed by the computer software while the surgeon performs a standardized surgical task. The computer software objectively evaluates economy of hand motion by calculating the total number of movements for each hand, movement velocity, trajectory, and hand travel distance. Subsequent validation studies on bench model simulators by a series of investigators have established HMA as a valid, objective, and reliable measure of surgical performance when applied to the assessment of open, laparoscopic, endoscopic, and microsurgical procedures.[3–6]

Technical performance on simulators in the surgical skills laboratory can differ significantly from that in the operating room. Standardized intraoperative competency assessments are particularly challenging in light of the significant variability between surgical procedures related to differences among patients, members of the surgical team (surgical assistants, nurses, and anesthesiologists), and instrumentation. Consequently, establishing the predictive validity of laboratory-based surgical skill assessments with respect to intraoperative surgical performance is essential. The primary objectives of the current initiative were as follows: (1) establish the feasibility of performing live intraoperative HMA on real patients, (2) perform preliminary validation analyses on intraoperative HMA as an objective measure of technical skill, and (3) use HMA to construct competency-based surgical learning curves over time.

Methods

Surgical tasks

Two standardized surgical tasks performed on live patients were selected as part of this initiative. The first surgical task selected was microsurgical vasectomy reversal performed under general anesthetic. For standardization, the microsurgical suturing and knot-tying components of the re-anastomosis of the outer muscular layer of the vas deferens using 3 interrupted 9-0 nylon sutures were selected for analysis of economy of hand motion. The second surgical task selected was a complete no-scalpel vasectomy performed under local anesthetic. For each surgical task the instrumentation, instrument position, and surgical assistance (scrub nurse and surgical assistant) were standardized.

Subjects included both a novice and an experienced surgeon in the field of male reproductive medicine and surgery. The novice surgeon had no previous experience with vasectomy or microsurgical vasectomy reversal as the primary surgeon. The experienced surgeon was a fellowship-trained specialist in male reproductive surgery and a member of the surgical faculty within the Division of Urology at the University of Toronto. Approximately 75 microsurgical vasectomy reversals and 120 vasectomies are performed each year by the experienced surgeon. Informed consent was obtained from all patients and surgeons before study participation and institutional review board approval was obtained.

Measurement instruments and outcome measures

Measures of economy of hand motion were recorded serially on each standardized surgical task using the Patriot 3-dimensional hand motion tracking system manufactured by Pohlemus (Colchester, VT, USA).[7] Small (1 cm), lightweight (9.1 g), unobtrusive electromagnetic sensors were placed on the backs of the primary surgeon's hands and a stationary sensor was secured to a motionless part of the patient at a distance of less than 30 cm from the hand sensors. Hand orientation and positional data including total number of hand movements, hand velocity, trajectory, and hand travel distance were recorded and analyzed by the Pohlemus computer software system. The static accuracy of the hand motion sensors in the X, Y, and Z orientations is .06 of an inch.[7] For the novice surgeon, hand motion data were acquired serially over time for each index surgical case. For the experienced surgeon, economy of hand motion was measured at baseline and at the end of the study period.

Each surgical case was recorded on digital video for subsequent unedited review by 2 blinded, experienced, and assessment-trained surgeons.[8–11] Assessment instruments used to evaluate the surgical videos included previously validated global rating scales, task-specific surgical checklists, and final product ratings adapted to the standardized surgical task.[12–15] Surgical checklists are a detailed, dichotomous (performed correctly/incorrectly), and task-specific evaluation instrument in which the surgeon is given credit for items on the checklist that are performed correctly and no credit for items performed incorrectly or not performed at all. Global rating scales consist of multiple domains pertinent to the specific surgical task (ie, respect for tissue, flow of the surgery, instrument handling), each rated on a behaviorally anchored numeric scale. Assuming that good processes (ie, technical skills) yield good end results, final product ratings assess the quality of the final products of surgical intervention. Scores from the 2 surgeon evaluators were combined to yield a single mean score.

Statistical analysis

Objective measures of economy of hand motion were correlated directly with blinded case-matched assessments of technical skill by experienced surgeons using 2-tailed Pearson (r) calculations and SPSS (Chicago, IL, USA) statistical software. Serial hand motion data from the novice and experienced surgeon were compared graphically with establish competency-based learning curves over time.