Knee, Shoulder, and Fundamentals of Arthroscopic Surgery Training: Validation of a Virtual Arthroscopy Simulator

Josef N. Tofte, M.D., Brian O. Westerlind, B.A., Kevin D. Martin, D.O., Brian L. Guetschow, B.S., M.A., Bastián Uribe-Echevarria, M.D., Chamnanni Rungprai, M.D., and Phinit Phisitkul, M.D.

Purpose: To validate the knee, shoulder, and virtual Fundamentals of Arthroscopic Training (FAST) modules on a virtual arthroscopy simulator via correlations with arthroscopy case experience and postgraduate year. **Methods:** Orthopaedic residents and faculty from one institution performed a standardized sequence of knee, shoulder, and FAST modules to evaluate baseline arthroscopy skills. Total operation time, camera path length, and composite total score (metric derived from multiple simulator measurements) were compared with case experience and postgraduate level. Values reported are Pearson r; alpha = 0.05. **Results:** 35 orthopaedic residents (6 per postgraduate year), 2 fellows, and 3 faculty members (2 sports, 1 foot and ankle), including 30 male and 5 female residents, were voluntarily enrolled March to June 2015. *Knee*: training year correlated significantly with year-averaged knee composite score, $r = 0.92$, $P = .004$, 95% confidence interval (CI) = 0.84, 0.96; operation time, $r = -0.92$, $P = .004$, 95% CI = −0.96, −0.84; and camera path length, $r = -0.97$, $P = .0004$, 95% CI = −0.98, −0.93. Knee arthroscopy case experience correlated significantly with composite score, $r = 0.58$, $P = .0008$, 95% CI = 0.27, 0.77; operation time, $r = -0.54$, $P = .002$, 95% CI = −0.75, −0.22; and camera path length, $r = -0.62$, $P = .0003$, 95% CI = −0.8, −0.33. *Shoulder*: training year correlated strongly with average shoulder composite score, $r = 0.90$, $P = .006$, 95% CI = 0.81, 0.95; operation time, $r = -0.94$, $P = .001$, 95% CI = −0.97, −0.89; and camera path length, $r = -0.89$, $P = .007$, 95% CI = −0.95, −0.80. Shoulder arthroscopy case experience correlated significantly with average composite score, $r = 0.52$, $P = .003$, 95% CI = 0.2, 0.74; strongly with operation time, $r = -0.62$, $P = .0002$, 95% CI = −0.8, −0.33; and camera path length, $r = -0.37$, $P = .044$, 95% CI = −0.64, −0.01, by training year. *FAST*: training year correlated significantly with 3 combined FAST activity average composite scores, $r = 0.81$, $P = .0279$, 95% CI = 0.65, 0.90; operation times, $r = -0.86$, $P = .012$, 95% CI = −0.93, −0.74; and camera path lengths, $r = -0.85$, $P = .015$, 95% CI = −0.92, −0.72. Total arthroscopy cases performed did not correlate significantly with overall FAST performance. **Conclusions:** We found significant correlations between both training year and knee and shoulder arthroscopy experience when compared with performance as measured by composite score, camera path length, and operation time during a simulated diagnostic knee and shoulder arthroscopy, respectively. Three FAST activities demonstrated significant correlations with training year but not arthroscopy case experience as measured by composite score, camera path length, and operation time. **Clinical Relevance:** We attempt to validate an arthroscopy simulator that could be used to supplement arthroscopy skills training for orthopaedic residents.

From the Department of Orthopaedics and Rehabilitation, University of Iowa Hospitals and Clinics (J.N.T., B.O.W., B.U-E., C.R., P.P.), Iowa City, Iowa; William Beaumont Army Medical Center (K.D.M.), El Paso, Texas; and University of Iowa Roy J. and Lucille A. Carver College of Medicine (B.L.G.), Iowa City, Iowa, U.S.A.

The authors report the following potential conflicts of interest or sources of funding: P.P. receives support from Smith & Nephew and Arthrex (consultancy); First Ray and Mortise Medical (stock/stock options).

Received April 1, 2016; accepted September 20, 2016.

Address correspondence to Josef N. Tofte, M.D., Department of Orthopaedics and Rehabilitation, University of Iowa Hospitals and Clinics, 200 Hawkins Drive, Iowa City, IA 52242, U.S.A. E-mail: jntofte@gmail.com

0749-8063/16252/$36.00

http://dx.doi.org/10.1016/j.arthro.2016.09.014

Orthopaedic resident education is evolving in order to accommodate the Accreditation Council for Graduate Medical Education work hour restrictions and mandated case log requirements.[1] With limitations on residency hours and thus overall training time, these changes have forced educators and training programs to diversify teaching strategies and create new learning opportunities for residents.[1] Altered curricula and resource-intensive operative room time have highlighted technical adjuncts to operating room instruction.[2,3] Among other modalities of instruction, surgical skill simulators hold promise as a valuable addition to real-world operating room experience.[4,5] However, new surgical simulators, although technically sophisticated, have yet to demonstrate lasting benefits from a training perspective.[3] Although it is generally assumed that in-person operative room experience provides the most valuable learning experience, well-executed simulators could enrich surgical education significantly by allowing new trainees to safely gain experience with technically difficult skills.

Although a variety of different arthroscopic simulators have been used in resident education and evaluated as learning tools, only a few studies have used and validated the recently developed virtual reality arthroscopy simulators.[2,6-12] The purpose of this study was to validate the knee, shoulder, and virtual Fundamentals of Arthroscopic Training (FAST) modules on a virtual arthroscopy simulator via correlations with arthroscopy case experience and postgraduate year. We hypothesized that simulator performance as measured by composite score, camera path length, and operation time will correlate significantly with postgraduate training year and arthroscopy case experience during simulated knee and shoulder diagnostic arthroscopy and 3 FAST activities.

Methods

Following IRB approval, over the course of 2.5 months from March through June 2015, orthopaedic residents and faculty from a single institution were voluntarily enrolled in the study and tested using a skill evaluation sequence. Enrollment consisted of 2 email notifications of the study and a brief noncoercive verbal consent process. Inclusion criteria were any orthopaedic resident in the program, as well as fellows and faculty with routine arthroscopy experience. We excluded fellows and faculty without routine arthroscopy case exposure and medical students.

Our institution obtained a VirtaMed ArthroS (VirtaMed, Zurich, Switzerland) simulator for resident use using departmental funds. The cost of the simulator was $125,000. The simulator included knee, shoulder, and virtual FAST modules. The simulator has a console with a large computer screen and interchangeable knee, shoulder, and FAST modules (Fig 1). The simulator has tools including a mock camera, probe, grasper, and shaver. The knee and shoulder modules are anatomic models with simulated skin and internal structures with pre-made portals. The FAST module is a hollow dome-shaped module with multiple circumferential portals. It is used to simulate an empty virtual space where simulated objects can be triangulated, grasped, and manipulated using arthroscopy tools.

We developed a standardized sequence of the unit's modules to evaluate baseline arthroscopy skills. We selected a sequence of activities on all 3 modules that we felt would appropriately assess participants' skills via a variety of activities. We chose operation time, camera path length, and the composite score as the metrics we presumed would best capture differences between elite and beginner arthroscopists. Operation time and camera path length have been previously evaluated in multiple studies, including 2 studies of this particular simulator.[4,5,7,13] The composite metric includes both operative time and camera path length, as well as weighted measures of cartilage injury and tool path length.

The simulator was introduced to subjects via a standardized approach, with a brief explanation of the goals of the study and the function of the camera and modules. Subjects did not have exposure to the device before the experimental period. Subjects began with the FAST module,[14] and "Telescoping" was used as an orientation module to acclimate to the simulator environment. Subjects then proceeded through 1 trial of computer-prompted "Periscoping," "Trace the Lines," and "Gather the Stars." These activities test manual dexterity and basic faculty with arthroscopic tools. The modules were then exchanged sequentially for trials consisting of first a knee diagnostic arthroscopy and then a shoulder diagnostic arthroscopy. These diagnostic sequences were chosen from existing sequences on the simulator that guide the participant through palpation of a series of structures in the knee and the shoulder by "highlighting" the desired structure on the simulator model on screen and prompting the user to palpate a specific structure with the probe tool.

The data collected by the simulator was compiled and analyzed. The training year of all participants was anonymously recorded. The Accreditation Council for Graduate Medical Education case log record of knee and shoulder arthroscopy cases were retrieved for all trainees. For correlations with training year, each residency class was treated as a single data point. Despite this adjustment, the conclusion we present is still relevant and interesting. When looking at each residency class, fellows, and faculty as a data point, there is clearly shown progression measured by simulator metrics as training year increases. The primary outcome for knee, shoulder, and FAST modules was a correlation between averaged simulator performance by year for composite score, operation time, and camera path length correlated with postgraduate year. The secondary outcome was number of knee, shoulder, or total arthroscopy cases performed by each individual resident correlated with individual composite score, operation time, and camera path length irrespective of training year. For the FAST module, composite scores were averaged for 3 activities and operative times and camera path lengths were summed. Pearson correlation coefficient and P values (alpha = 0.05) are reported.

Results

Study participants included 6 residents per training year (all residents in the program), 1 foot and ankle