Arthroscopic Training Courses Improve Trainee Arthroscopy Skills: A Simulation-Based Prospective Trial

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Purpose: To evaluate the correlation between timed task performance on an arthroscopy shoulder simulator and participation in a standardized expert shoulder arthroscopy educational course. **Methods:** Orthopaedic trainees were voluntarily recruited from over 25 residency programs throughout the United States and Canada. Each trainee was tested on arrival at the Arthroscopy Association of North America orthopaedic learning center on a virtual reality arthroscopy shoulder simulator, and his or her performance was objectively scored. Each trainee's postgraduate year level was recorded, as was his or her experience in residency with shoulder arthroscopy as measured by Accreditation Council for Graduate Medical Education case-log totals. After the focused 4-day training curriculum consisting of didactics and cadaveric experience, each trainee was re-evaluated on the same simulator. Statistical analysis was performed to determine if participation in the course was associated with changes in simulation performance from before to after assessment. **Results:** Forty-eight trainees completed the testing. On completion of the course, trainees showed significant improvements in all objective measures recorded by the simulator. Total probe distance needed to complete the task decreased by 42% (from 420.4 mm to 245.3 mm, $P < .001$), arthroscope tip distance traveled decreased by 59% (from 194.1 mm to 80.2 mm, $P < .001$), and time to completion decreased by 38% (from 66.8 seconds to 41.6 seconds, $P < .001$). Highly significant improvements in all 3 measures suggest improved instrument handling, anatomic recognition, and arthroscopy-related visual-spatial ability. **Conclusions:** This study shows objective improvement in orthopaedic trainee basic arthroscopy skill and proficiency after a standardized 4-day arthroscopy training curriculum. The results validate the Arthroscopy Association of North America resident training course and its curriculum with objective evidence of benefit. **Level of Evidence:** Level III, prospective study of nonconsecutive participants.

Resident education is undergoing a massive paradigm shift toward proficiency-based curricula and evidence-based training programs. The American Council for Graduate Medical Education (ACGME) and Residency Review Committee are transitioning orthopaedic resident education to an increasingly standardized curriculum. This includes implementation of work-hour restrictions, surgical case-log minimums, core milestones, and required surgical simulation.[1,2] This model of education follows the Flexner ideology,[3] which encourages standardization of curricula that can be objectively measured, providing evidence-based outcomes. To comply with simulation mandates, programs are seeking standardized surgical training with demonstrated outcomes of improved surgical skill.

Arthroscopy education has been a major focus of educators because of its reproducibility and constantly expanding indications and techniques. Both national orthopaedic organizations and industry host multi-day arthroscopy educational courses. To date, none of these courses have been objectively evaluated with surgical skill as the primary outcome. Over the past 25 years, the Arthroscopy Association of North America (AANA) has hosted thousands of orthopaedic trainees

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Table 1. Demographic Factors

	Male (n = 40, 83%)		Female (n = 8, 17%)		Total (N = 48)	
	Median	IQR	Median	IQR	Median	IQR
Age, yr	30	2	29	4	30	2
Postgraduate year	3	0	3	1	3	0
Shoulder arthroscopies performed at baseline*	33	34	15	9	31	34

IQR, interquartile range (difference between third and first quartiles).

*Number of reported shoulder arthroscopy Current Procedural Terminology codes listed for the trainee in the official Accreditation Council for Graduate Medical Education or equivalent case-log database.

and has standardized its curriculum. Its curriculum, like others, consists of master instructors leading both classroom lectures and hands-on arthroscopy cadaveric didactics. During the resident education course, there is a 2:1 trainee-to-instructor ratio, allowing personalized instruction and step-by-step guidance from basic tasks to complex repairs.[4] This curriculum has been embraced throughout the years but has not been substantiated with any objective improvement after the course.

As resident training and arthroscopy training evolve together, both benefit from the development of evidence-based education. Residents are mandated to participate in simulation exercises; however, the term "simulation" has been defined loosely[2] to allow programs to individualize their training. Options range from simple Sawbones models (Pacific Research Laboratories) to high-fidelity virtual reality (VR) simulators. These high-fidelity VR simulators have been validated, with scores strongly correlating to surgical experience.[5-8] Recently, these VR simulators have also proved transfer validity to both knee[9] and shoulder[10] arthroscopy.

This investigation is a prospective observational study of orthopaedic surgery trainee performance before and after participation in an AANA resident arthroscopy training course. The purpose was to evaluate the correlation between timed task performance on an arthroscopy shoulder simulator and participation in a standardized expert shoulder arthroscopy educational course. We hypothesized that orthopaedic trainees would show improved performance in basic shoulder arthroscopy skills and proficiency as measured by a simulator after participation in the AANA resident training course.

Methods

Participants

After institutional review board approval, 99 orthopaedic surgery trainees of various postgraduate years (PGYs) were invited to participate in this study between October 2013 and June 2014. There were 3 courses during this time, and because of simulator availability limitations, the first and last courses were evaluated. Participants were from throughout North America and included over 20 different American programs and 3 Canadian programs. All trainees were contacted before arrival at the course and voluntarily agreed to participate. Participation in the resident education course was not affected by involvement in the study. The criteria for inclusion were ongoing training in an ACGME or equivalent orthopaedic training program and resident training course enrollment. The exclusion criterion was failure of the trainee to attend the entirety of the course. Previous arthroscopy experience varied by individual PGY in training and location of home training program. Demographic information and arthroscopy experience were collected at the onset of testing, including age, sex, PGY level, and ACGME or equivalent case-log data (Table 1). Each trainee's case log was maintained by the ACGME or equivalent, and cases were logged as per its guidelines.

Study Design

A prospective observational study was performed in which trainees, on arrival to the course, were tested on a validated arthroscopy shoulder simulator. During the course, they were not allowed any exposure to the simulator. On completion of the course, they immediately underwent a repeat evaluation on the simulator.

Simulation Testing

All simulation testing was performed in a controlled setting using the high-fidelity ARTHRO Mentor VR arthroscopy shoulder simulator (Simbionix, Cleveland, OH). This simulator is equipped with a high-definition monitor, a model shoulder, and 2 robotic haptic arms that allow force feedback when instruments are introduced into the shoulder (Fig 1). All testing was conducted using the simulator's blue sphere program, which places blue spheres at various anatomic locations within the glenohumeral joint. Trainees locate and palpate each blue sphere as the simulator records camera distance (in millimeters), probe distance (in millimeters), and time required to complete the examination (in seconds). This testing model was selected because it has been validated and the metrics have been correlated to surgical experience by 2 previous studies.[6,8]

Fig 1. Trainee demonstrating simulation-based diagnostic left shoulder examination.

All trainees were given a brief orientation to the simulator and given a practice session to ensure the trainees understood the task and acquired an appreciation for the force-generated haptic feedback. After the orientation session, the trainees completed 3 blue sphere diagnostic examinations. All testing was supervised by the same fellowship-trained surgeon to ensure consistency. During testing, trainees did not receive any coaching or assistance. The only data produced were those recorded by the simulator. The trainees then participated in and completed the resident education course curriculum. At the completion of the course, trainees performed an additional simulator examination using the same testing protocol.

Arthroscopy Training

After the initial simulation examination, all trainees immediately began participation in the resident education course. The course is specifically designed to improve motor skills and emphasizes basic arthroscopic techniques using shoulder and knee cadaveric simulator models. The training consists of lecture-based learning, dry bench-top box trainers, and cadaveric wet laboratory training using modern arthroscopy equipment and techniques. Throughout the training, there is a 2:1 trainee-to-instructor ratio, maximizing direct learning and hands-on experiences. The course curriculum is accredited by the Accreditation Council for Continuing Medical Education to provide trainees with 27.75 category 1 credit hours of training. During the first day of training, trainees used the Fundamentals of Arthroscopic Surgery Training (FAST) box trainer (Sawbones, Pacific Research Laboratories), which allows for practicing arthroscopic triangulation and equipment manipulation. The second day and third day were focused on cadaveric knee and shoulder arthroscopic procedures, respectively. The final day of training consisted of complex shoulder reconstruction and open anatomic dissection.

Statistical Analysis

Initially, standard descriptive statistics were calculated for all variables of interest. Mathematical means and standard deviations were calculated for continuous variables when the data were normally distributed. When continuous data were not normally distributed or when data were ordinal in nature, then medians and interquartile ranges were calculated because the interquartile range is the appropriate measure of variability to report with median values when the data are not normally distributed. Frequencies and proportions were calculated for categorical variables. To determine whether there were significant changes in simulation performance from before intervention to after intervention, we used dependent *t* tests. All statistical analyses were completed using STATA/SE software (version 10.1; StataCorp, College Station, TX), and a type I error rate of $P < .05$ was used to assess statistical significance. Post hoc power analysis (Table 2) confirmed the number of participants was sufficient to determine a difference in each of our 3 performance measures.

Results

Ninety-nine trainees enrolled in the courses. Eighty-four attended every day of the course. Forty-eight trainees completed both sets of testing. The study group of orthopaedic trainees consisted of 40 men and 8 women. The study group comprised one PGY-1 trainee, six PGY-2 trainees, thirty-two PGY-3 trainees, six PGY-4 trainees, and three PGY-5 trainees, with shoulder arthroscopy case logs ranging from 0 to 215, with a median of 31 (interquartile range, 34). A summary of demographic information for the study sample is presented in Table 1.

After completing the 4-day standardized arthroscopy curriculum, trainees showed significant improvements in all dimensions measured by the simulator task (Table 2). Trainees significantly decreased the probe distance traveled during the simulation task from 420.4 mm (±206.9 mm) before the course to 245.2 mm (±91.6 mm) after the course. This corresponded to a 42% decrease in probe distance. Trainees also significantly decreased the camera distance traveled during the simulation task after the course, from 194.1 mm (±112.1 mm) to 80.2 mm (±46.9 mm). On average, there was a 59% decrease in camera distance traveled during the simulation task. Finally, the time required to complete the simulation task was significantly lower after the 4-day course. The time to completion decreased from 66.8 seconds (±26.8 seconds) to

Table 2. Pre- to Postintervention Within-Group Comparisons for Simulation Variables

	Before Intervention		After Intervention			
	Mean	Standard Deviation	Mean	Standard Deviation	*P* Value	Observed Power (Post Hoc Power Analysis)
Camera distance, mm*	194.1	112.1	80.2	46.9	<.001	1.00
Probe distance, mm†	420.4	206.9	245.3	91.6	<.001	0.99
Time, s‡	66.8	26.8	41.6	10.5	<.001	1.00

*Distance the arthroscope traveled to complete the diagnostic examination.
†Distance the probe traveled to palpate the anatomic location within the diagnostic examination.
‡Time required to identify and palpate each anatomic location within the diagnostic examination.

41.6 seconds (±10.5 seconds). Overall, participants reduced their time to complete the simulation task by 38% after the course. In addition to the observation of significant improvements across all simulation variables after course participation, variability as measured by standard deviation decreased significantly among participants from pre- to post-course assessment (Table 2).

Discussion

Our study found that after participation in the AANA resident arthroscopy skills course, orthopaedic trainees showed significant improvements in all measures recorded by a VR arthroscopy simulator. This includes the distance traveled by the arthroscopic probe, the distance traveled by the arthroscope, and the time to completion. This standardized curriculum, consisting of didactics, box trainers, and instructor-led hands-on cadaveric experience, was followed immediately by improved basic arthroscopy skills as measured on a VR shoulder simulator. These data also objectively validate the AANA resident training course and curriculum.

After the ACGME implementation of mandatory simulation, training programs have been searching for evidence-based research showing improved surgical skill and performance after training. To date, limited evidence exists as to objective improvements in performance after arthroscopy teaching, which forces trainees and their programs to allocate resources toward what is perceived as likely to improve skills. This study shows objective robust skills improvement after the AANA resident training course.

Using arthroscopy simulators to evaluate basic surgical skill has become one of the most commonly performed simulation studies[7,9,11,12] because the results serve to validate the simulator and its testing model. Historically, high-fidelity VR shoulder simulators have been able to objectively decipher surgical skill between novice and expert arthroscopists.[5-7,13] Furthermore, longitudinal studies by Gomoll et al.[14] and Martin et al.[8] were able to show that a simulator model could be used to follow progression of surgical skills with repeated evaluations over time. Our study similarly follows this model with repeated simulation evaluation after surgical training showing objective improvement on a simulator model.

The strengths of this study include its validated objective outcome measures. Nearly all simulation studies are underpowered because of program size and trainee availability.[15] Post hoc power analyses suggest that sample size and observed power in our study were sufficient to evaluate all outcomes of interest (Table 2). The specific simulator used and its testing metrics have previously been validated[6] and have also been shown to correlate with surgical experience.[8] This study was also strengthened by the regimented consistency of the AANA resident training curriculum,[4] which allows for little variation from one training course to the next. Finally, all testing was supervised by a single researcher.

Limitations

Limitations of our study include the lack of an independent control group, lack of a comparative cadaveric testing model, and possible selection bias. Without a control group, one could speculate that repeated exposures on a simulator could improve performance. To mitigate this phenomenon, trainees were blinded to their simulation performance score and each trainee was tested 3 times to mitigate outliers in performance. Given the very limited time exposure to the simulator relative to the extensive work with cadaveric specimens, we believe that improvement in these objective measures is far more attributable to the course. Specifically, the total exposure time to the simulator relative to the remainder of even just the hands-on portion of the course was very small. Average pre-course exposure was well below 5 minutes, and the total time of the course was in excess of 25 hours, with most of the time spent with cadaveric specimens. A comparative cadaveric testing model would have further strengthened the study, possibly reflecting in vivo surgical skill improvement. A potential selection bias likely exists because all participants were volunteers and those who chose not to participate may have had lower overall surgical skills or been less motivated to improve during the course. However, including participants who did not participate in the entire course would not offer an accurate reflection of the course's potential for trainee improvement. Furthermore, it is unclear what aspects of the course are responsible for the most improvement, and this study does not attempt to delineate what aspects are most helpful to trainees. Without long-term follow-up testing, it is difficult to assess how long these improvements are sustained as participants return to their training programs. This study was made up of a highly disproportionate percentage of trainees in PGY-3, as well as male participants, making subgroup analysis very limited. We would anticipate that there would be a ceiling effect for trainees more advanced in their education, and future studies should aim to have broader representation across levels of training to answer this important question.

Conclusions

This study shows objective improvement in orthopaedic trainee basic arthroscopy skill and proficiency after a standardized 4-day arthroscopy training curriculum. The results validate the AANA resident training course and its curriculum with objective evidence of benefit.

References

1. Accreditation Council for Graduate Medical Education. ACGME program requirements for residency education in general surgery. http://www.acgme.org/acwebsite/tabid/150/ProgramandInstitutionalAccreditation/SurgicalSpecialties/Surgery.aspx. Accessed October 4, 2013.
2. Accreditation Council for Graduate Medical Education. Orthopaedic surgery. http://www.acgme.org/acgmeweb/tabid/140/ProgramandInstitutionalAccreditation/SurgicalSpecialties/OrthopaedicSurgery.aspx. Accessed October 4, 2013.
3. Flexner A. *Medical education in the United States and Canada: A report to the Carnegie Foundation for the Advancement of Teaching*. Stanford, CA: Carnegie Foundation for the Advancement of Teaching, 1910.
4. Arthroscopy Association of North America. Resident course. http://www.aana.org/CMECoursesMeetings/MastersExperience/ResidentCourse/tabid/928/Default.aspx. Accessed September 27, 2014.
5. Pedowitz RA, Esch J, Snyder S. Evaluation of a virtual reality simulator for arthroscopy skills development. *Arthroscopy* 2002;18:E29.
6. Martin KD, Belmont PJ Jr, Schoenfeld AJ, Todd M, Cameron KL, Owens BD. Arthroscopic basic task performance in shoulder simulator model correlates with similar task performance in cadavers. *J Bone Joint Surg Am* 2011;93:e1271-e1275.
7. Gomoll AH, O'Toole RV, Czarnecki J, Warner JJ. Surgical experience correlates with performance on a virtual reality simulator for shoulder arthroscopy. *Am J Sports Med* 2007;35:883-888.
8. Martin KD, Cameron K, Belmont PJ Jr, Schoenfeld AJ, Owens BD. Shoulder arthroscopy simulator performance correlates with resident and shoulder arthroscopy experience. *J Bone Joint Surg Am* 2012;94:e160.
9. Howells NR, Gill HS, Carr AJ, Price AJ, Rees JL. Transferring simulated arthroscopic skills to the operating theatre: A randomized blinded study. *J Bone Joint Surg Br* 2008;90:494-499.
10. Henn RF III, Shah N, Warner JJ, Gomoll AH. Shoulder arthroscopy simulator training improves shoulder arthroscopy performance in a cadaveric model. *Arthroscopy* 2013;29:982-985.
11. Cannon WD, Nicandri GT, Reinig K, Mevis H, Wittstein J. Evaluation of skill level between trainees and community orthopaedic surgeons using a virtual reality arthroscopic knee simulator. *J Bone Joint Surg Am* 2014;96:e57.
12. Butler A, Olson T, Koehler R, Nicandri G. Do the skills acquired by novice surgeons using anatomic dry models transfer effectively to the task of diagnostic knee arthroscopy performed on cadaveric specimens? *J Bone Joint Surg Am* 2013;95:e15(1-8).
13. Smith S, Wan A, Taffinder N, Read S, Emery R, Darzi A. Early experience and validation work with Procedicus VA—The Prosolvia virtual reality shoulder arthroscopy trainer. *Stud Health Technol Inform* 1999;62:337-343.
14. Gomoll AH, Pappas G, Forsythe B, Warner JJ. Individual skill progression on a virtual reality simulator for shoulder arthroscopy: A 3-year follow-up study. *Am J Sports Med* 2008;36:1139-1142.
15. Modi CS, Morris G, Mukherjee R. Computer-simulation training for knee and shoulder arthroscopic surgery. *Arthroscopy* 2010;26:832-840.