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Arthroscopy Skills Development With a Surgical Simulator

A Comparative Study in Orthopaedic Surgery Residents

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Background: Surgical simulation has become increasingly relevant to orthopaedic surgery education and could translate to improved operating room proficiency in orthopaedic surgery trainees.

Purpose: To compare the arthroscopic performance of junior orthopaedic surgery residents who received training with a knee and shoulder arthroscopy surgical simulator with those who received didactic training.

Study Design: Controlled laboratory study.

Methods: Fourteen junior orthopaedic surgery residents at a single institution were randomized to receive knee and shoulder arthroscopy training with a surgical simulator (n = 8) or didactic lectures with arthroscopy models (n = 6). After their respective training, performance in diagnostic knee and shoulder arthroscopy was assessed using a cadaveric model. Time to completion and assessment of arthroscopic handling using a subjective injury grading index (scale, 1-10) was then used to evaluate performance in final cadaveric testing.

Results: Orthopaedic surgery residents who trained with a surgical simulator outperformed the didactic-trained residents in shoulder arthroscopy by time to completion (–35%; $P = .02$) and injury grading index (–35%; $P = .01$). In addition, a trend toward improved performance of knee arthroscopy by the simulator-trained group was found by time to completion (–36%; $P = .09$) and injury grading index ($P = .08$).

Conclusion: In this study, junior orthopaedic surgery residents who trained with a surgical simulator demonstrated improved arthroscopic performance in both knee and shoulder arthroscopy. However, future validation of surgical simulator training for orthopaedic surgery residents remains warranted.

Clinical Relevance: Surgical skill development with an arthroscopy surgical simulator could translate to improved arthroscopy performance in the operating room.

Keywords: virtual reality; surgical simulator; surgical education; arthroscopy simulator

Development of arthroscopy surgical skills among orthopaedic surgery residents can be varied because of the training experiences provided. The surgical experience of residents has long been tied to an apprenticeship model in the operating room under the guidance of a senior surgeon.[14] Still the mastery of any surgical operation often requires extensive training, with arthroscopy proficiency being no different.

In July 2013, the Accreditation Council for Graduate Medical Education changed requirements for orthopaedic surgery residents to obtain basic arthroscopy training in their first year of training. However, postgraduate year 1 (PGY 1) resident training also consists of 6 months of structured education on nonorthopaedic rotations.[1] These expanding requirements can leave a limited period of time for junior orthopaedic surgery residents to obtain early surgical training. Work-hour restrictions have also

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prompted concern over limited operative experience.[5,11,15] As the training requirements have evolved, residency programs have also been placed under pressure to adapt to these parameters while still providing high-quality educational experiences for residents in both operative and classroom environments.

Previous work by Howells et al[10] showed that surgical simulator training leads to improved operating room performance in junior orthopaedic residents. Increased experience with the simulator showed improvements with time to completion, hand movement analysis, global rating scale, and assigned competencies in PGY 1 and 2 residents. These findings have not been isolated to orthopaedic education, as general surgery,[6,19] ophthalmology,[18] and even aviation training has shown similar benefits with virtual reality training.[4] As this technology becomes readily available, junior-level orthopaedic surgery residents may show further benefit with an arthroscopy simulator that may enrich the educational experience, provide early exposure, and translate to improved arthroscopic performance. Accordingly, simulator training at the junior level may also mitigate risks to patient safety.

In this prospective randomized study, our aim was to assess the performance outcomes of junior orthopaedic surgery residents who receive training with a knee and shoulder arthroscopy simulator in comparison with those who receive didactic training. We hypothesized that residents who train with the arthroscopy surgical simulator will demonstrate improved performance by time to completion of a diagnostic arthroscopy checklist and will demonstrate greater surgical skill in arthroscopy.

METHODS

This was a prospective randomized single-blinded study designed to compare the arthroscopic performance of junior orthopaedic surgery residents at a single institution who trained with an arthroscopy surgical simulator. PGY 1 and 2 residents at a single institution were designated into 2 groups using simple randomization to either train on a virtual reality surgical simulator (Insight Arthro VR; GMV) (group 1) for a total of 2.5 hours (n = 8) or receive 2 hours of didactic lectures on basic arthroscopy, which included the use of arthroscopy instruments and knee/shoulder models (group 2) (n = 6). Randomization to each group was computer generated and took place before start of the study. After their respective training, residents were then assessed in their arthroscopic performance using a cadaveric model of both shoulder and knee arthroscopy. No resident in this study had simulation training experience before the study, along with no previous rotation that encompassed shoulder or knee arthroscopy. Demographic information was obtained for each participant, including age, sex, and PGY level.

Arthroscopy training using the surgical simulator was modeled to replicate the operative experience. The simulator involved a high-definition monitor with 2 robotic arms that involve force-reflective technology with interactive live feedback provided to the participant. The camera used in the training modules represented a 30° camera for both shoulder and knee modules. The training modules specific to the simulator included a "blue sphere" program, which designated landmarks to be probed as part of the diagnostic arthroscopy modules as previously described[12] (see the Video Supplement). Simulator modules performed in this study included basic task performance comparable with the diagnostic arthroscopy checklist. Higher level task performance or procedure-based modules were not utilized as part of the simulator training. Also, no scoring of the simulator modules was recorded as part of the resident training. This type of training program with a surgical simulator has been correlated with the experience and performance in a cadaveric model.[12]

Didactic lectures received by study participants included a PowerPoint (Microsoft Corp) presentation on basic arthroscopy. This included the use of arthroscopy instruments used in the operating room, steps and procedural instructions involved in diagnostic arthroscopy of the shoulder and knee, and knee/shoulder models to be handled by the residents to gain familiarity. Proper positioning of the arthroscope and basic functions were also covered. The didactic lecture also used images of anatomic landmarks to be encountered during basic arthroscopy tasks with stepwise instruction of a diagnostic evaluation.

After the completion of arthroscopy training, a cadaveric model of both shoulder and knee arthroscopy was used to assess arthroscopic performance in both groups. Testing included time required to complete a standardized arthroscopy checklist for both shoulder and knee cadavers (see the Appendix, available online at http://ajsm.sagepub.com/supplemental), and a generated injury grading index (IGI) to assess dexterity, probe collisions, and presumed intra-articular injury. The IGI was created as a psychometric scale graded from 1 to 10 (1 being best), similar to a linear progression such as the visual analog scale, to subjectively evaluate for potential intra-articular injury (Table 1). The 2 senior investigators (A.L. and A.S.R.) on this study determined each resident's IGI based on direct observation during cadaveric testing. Both senior investigators were blinded to the randomization of each resident's respective training before final cadaveric testing. Random assortment of intergroup participants was also used during cadaveric testing. Checklists were used to assess performance, and time to completion was used for both the shoulder and knee cadavers. Portal landmarks and incisions were made before cadaveric testing so that instruments could be introduced in a more facile manner with diminished effect on timing measurements for each participant.

Study approval was obtained by our institutional review board. No external funding was received for this study.

Overall summary statistics were calculated in terms of means and standard deviations for continuous variables and frequencies (age, time to completion, and IGI score) and percentages for categorical variables (sex and PGY level). Group differences for discrete variables were evaluated using chi-square or Fisher exact test. Statistical significance was set at alpha equal to 0.05. All analyses were performed using SPSS version 14.0 (IBM Corp).

TABLE 1
Injury Grading Index Performance Scale

Score	Description of Performance
Excellent arthroscopic handling	
1	With no intra-articular injury
2	With minor intra-articular injury
Very good arthroscopic handling	
3	With minor intra-articular injury
4	With moderate intra-articular injury
Fair arthroscopic handling	
5	With minor intra-articular injury
6	With moderate intra-articular injury
Poor arthroscopic handling	
7	With moderate intra-articular injury
8	With significant intra-articular injury
Very poor arthroscopic handling	
9	With moderate intra-articular injury
10	With significant intra-articular injury

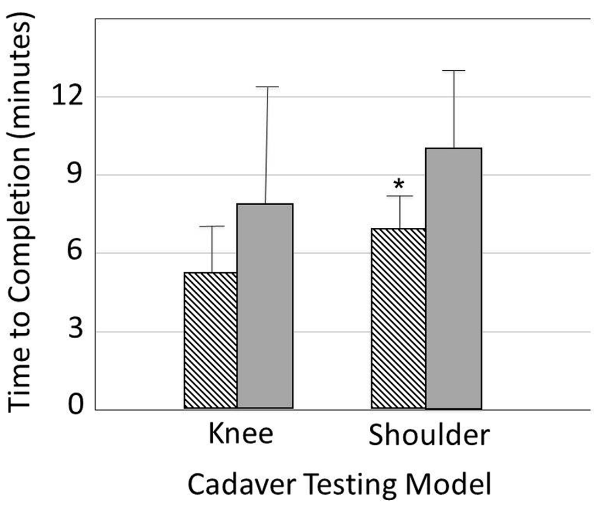

Figure 1. Time to completion of diagnostic arthroscopy checklist in knee and shoulder cadaver testing. The striped bars represent the group who trained on the simulator, and the shaded bars denote the group who received didactic training. *$P < .05$.

RESULTS

Fourteen junior-level orthopaedic surgery residents in either their PGY 1 or 2 participated in this study, with 8 residents randomized to group 1 (surgical simulator training) and 6 to group 2 (didactic training). The average age of the participants was 29.4 years (range, 26-32 years) in group 1 and 29.0 (range 27-32) in group 2 (P = .75). There was no difference in sex between groups (group 1: 7 men, group 2: 4 men; P = .76). In addition, level of training based on PGY was equivalent between study groups (group 1: 90% PGY 1, group 2: 80% PGY 1; P = .76).

TABLE 2
Injury Grading Index[a]

Arthroscopy Model	Simulator-Trained Group (n = 8)	Didactic-Trained Group (n = 6)	P Value
Knee	4.0 ± 1.0	5.3 ± 1.5	.08
Shoulder	3.6 ± 0.9	5.5 ± 1.5	.01[b]

[a]Values are expressed as mean ± SD.
[b]Statistically significant between-group difference ($P < .05$).

In cadaveric testing, the simulator-trained group demonstrated a shorter time to checklist completion in shoulder arthroscopy (group 1: 6.4 ± 1.6 min, group 2: 9.9 ± 3.2 min; P = .02). A trend toward improved performance in knee arthroscopy was found in the simulator-trained group (group 1: 5.1 ± 1.8 min, group 2: 8.0 ± 4.1 min; P = .09) (Figure 1). In addition, the simulator-trained group had improved IGI scores in cadaveric testing models of shoulder arthroscopy (group 1: 3.6 ± 0.9, group 2: 5.5 ± 1.5; P = .01) and a trend found in knee arthroscopy (group 1: 4.0 ± 1.0, group 2: 5.3 ± 1.5; P = .08) (Table 2).

DISCUSSION

Surgical simulation has become increasingly relevant to orthopaedic surgery education and has been shown to be an effective tool for arthroscopy training.[3,8,16] In our prospective randomized study, we found that training with a surgical simulator translated to improved performance in diagnostic shoulder arthroscopy in junior-level residents. Improvements were found in time to completion and IGI for shoulder arthroscopy. While the simulator-trained group also showed a trend toward improved skill in knee arthroscopy, the differences found did not reach significance. Still, these early improvements of the simulator-trained group in knee arthroscopy by completion time and instrument handling may manifest a more evident effect in eventual clinical skill acquisition. Potential effects could extend beyond reaching competence in arthroscopy, leading to improved clinical care by means of simulator training.

Martin et al[13] showed that simulator training in residents and attending surgeons led to improved performance in a cadaveric model. In addition, it has been demonstrated that arthroscopic skill achieved in the operating room correlates to performance on an arthroscopic surgical simulator.[3] Invariably, the operating room environment could also have an effect on a residents' arthroscopy performance. Cannon et al[3] clearly denoted as well that performance in their simulator study cannot be presumed to be interchangeable with arthroscopic proficiency. While simulator training in our study was shown to improve arthroscopic performance in residents, it remains unknown whether acquisition of skills using a surgical simulator can ultimately lead to greater proficiency in arthroscopy in our study population.

As utilized in previous studies, our outcomes included time required to complete a diagnostic arthroscopy checklist.[7,8,17,20] Our study showed that simulator-trained residents showed improved time to completion for diagnostic shoulder arthroscopy, yet this finding was not found in knee arthroscopy. Possible factors related to this finding could have been the amount of time allowed for training. It is possible that if increased training time with the surgical simulator had been given, an objective difference may have been found. In addition, this study may suggest that a disparity exists in the training required for shoulder and knee arthroscopy. It is unknown whether proficiency in shoulder and knee arthroscopy would require varying levels of experience. In addition, video game experience was not accounted for in our study population, although no standardized assessment of video game experience related to arthroscopy development currently exists. Subjective perception of the arthroscopy experience in the shoulder and knee models was not accounted for in this study, although overall time to completion for both groups was highest in shoulder arthroscopy. This highlights the limitation that our study remains underpowered; it is also limited by the number of junior residents at our institution.

Qualitative evaluation of arthroscopy performance was assessed by use of an IGI. By this measure, our study showed that simulator trainees demonstrated improved instrument handling in shoulder arthroscopy. As seen in previous studies, subjective measures of arthroscopic performance have been used.[9,10] As suggested by Atesok et al,[2] direct observation by senior-level experts may not be a reliable method for assessment, as seen in determining the accuracy of instrument handling with potential recall bias occurring because of the retrospective nature of the evaluation. Still the push for a validated assessment in virtual reality arthroscopy would help to judge performance with this new training model.

In conclusion, this study suggests that junior orthopaedic surgery residents who train with a surgical simulator demonstrate improved arthroscopic performance. Surgical simulator training led to improved performance in cadaveric testing of shoulder arthroscopy as compared with that of the residents who did not receive the same simulator training. Additional future validation of surgical simulator training for orthopaedic surgery residents remains warranted, with further studies needed to address whether skills acquired with the simulator can lead to proficiency in the operating room setting.

A Video Supplement for this article is available in the online version or at http://ajsm.sagepub.com/supplemental.

REFERENCES

1. Accreditation Council for Graduate Medical Education. *ACGME Program Requirements for Graduate Medical Education in Orthopaedic Surgery*. Chicago, IL: Accreditation Council for Graduate Medical Education; 2014.
2. Atesok K, Mabrey JD, Jazrawi LM, et al. Surgical simulation in orthopaedic skills training. *J Am Acad Orthop Surg*. 2012;20(7):410-422.
3. Cannon WD, Nicandri GT, Reinig K, et al. Evaluation of skill level between trainees and community orthopaedic surgeons using a virtual reality arthroscopic knee simulator. *J Bone Joint Surg Am*. 2014;96(7):e57.
4. Fried MP, Satava R, Weghorst S, et al. The use of surgical simulators to reduce errors. In Henriksen K, Battles JB, Marks ES, et al, eds. *Advances in Patient Safety: From Research to Implementation*. Vol 4. Rockville, MD: Agency for Healthcare Research and Quality; 2005.
5. Friedlaender GE. The 80-hour duty week: rationale, early attitudes, and future questions. *Clin Orthop Relat Res*. 2006;449:138-142.
6. Gallagher AG, Seymour NE, Jordan-Black JA, et al. Prospective, randomized assessment of transfer of training (ToT) and transfer effectiveness ratio (TER) of virtual reality simulation training for laparoscopic skill acquisition. *Ann Surg*. 2013;257(6):1025-1031.
7. Gomoll AH, O'Toole RV, Czarnecki J, et al. Surgical experience correlates with performance on a virtual reality simulator for shoulder arthroscopy. *Am J Sports Med*. 2007;35(6):883-888.
8. Gomoll AH, Pappas G, Forsythe B, et al. Individual skill progression on a virtual reality simulator for shoulder arthroscopy: a 3-year follow-up study. *Am J Sports Med*. 2008;36(6):1139-1142.
9. Henn RF 3rd, Shah N, Warner JJ, et al. Shoulder arthroscopy simulator training improves shoulder arthroscopy performance in a cadaveric model. *Arthroscopy*. 2013;29(6):982-985.
10. Howells NR, Gill HS, Carr AJ, et al. Transferring simulated arthroscopic skills to the operating theatre: a randomised blinded study. *J Bone Joint Surg Br*. 2008;90(4):494-499.
11. Lopez G, Tornetta P, 3rd, Mazzocca AD, et al. How do you educate someone to have the skills of an orthopaedic surgeon? *Instr Course Lect*. 2014;63:487-494.
12. Martin KD, Belmont PJ, Schoenfeld AJ, et al. Arthroscopic basic task performance in shoulder simulator model correlates with similar task performance in cadavers. *J Bone Joint Surg Am*. 2011;93(21):e1271-e1275.
13. Martin KD, Cameron K, Belmont PJ, et al. Shoulder arthroscopy simulator performance correlates with resident and shoulder arthroscopy experience. *J Bone Joint Surg Am*. 2012;94(21):e160.
14. Michelson JD. Simulation in orthopaedic education: an overview of theory and practice. *J Bone Joint Surg Am*. 2006;88(6):1405-1411.
15. Peabody T, Nestler S, Marx C, et al. Resident duty-hour restrictions-who are we protecting? AOA critical issues. *J Bone Joint Surg Am*. 2012;94(17):e131.
16. Pedowitz RA, Marsh JL. Motor skills training in orthopaedic surgery: a paradigm shift toward a simulation-based educational curriculum. *J Am Acad Orthop Surg*. 2012;20(7):407-409.
17. Reznick RK, MacRae H. Teaching surgical skills: changes in the wind. *N Engl J Med*. 2006;355(25):2664-2669.
18. Solverson DJ, Mazzoli RA, Raymond WR, et al. Virtual reality simulation in acquiring and differentiating basic ophthalmic microsurgical skills. *Simul Healthc*. 2009;4(2):98-103.
19. Stefanidis D, Scerbo MW, Montero PN, et al. Simulator training to automaticity leads to improved skill transfer compared with traditional proficiency-based training: a randomized controlled trial. *Ann Surg*. 2012;255(1):30-37.
20. Tashiro Y, Miura H, Nakanishi Y, et al. Evaluation of skills in arthroscopic training based on trajectory and force data. *Clin Orthop Relat Res*. 2009;467(2):546-552.