Topics in Training

Arthroscopic Basic Task Performance in Shoulder Simulator Model Correlates with Similar Task Performance in Cadavers

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Background: Attainment of the technical skill necessary to safely perform arthroscopic procedures requires the instruction of orthopaedic surgery residents in basic arthroscopic skills. Although previous studies involving shoulder arthroscopy simulators have demonstrated a correlation between task performance and the level of prior arthroscopic experience, data demonstrating the correlation of simulator performance with arthroscopic skill in a surgical setting are scarce. Our goal was to evaluate the correlation between timed task performance in an arthroscopic shoulder simulator and timed task performance in a cadaveric shoulder arthroscopy model.

Methods: Subjects were recruited from among residents and attending surgeons in an orthopaedic surgery residency program. Each subject was tested on an arthroscopic shoulder simulator and objectively scored on the basis of the time taken to complete a standardized object selection program. After an interval of at least two weeks, each subject was then tested on a cadaveric shoulder arthroscopy model designed to replicate the shoulder arthroscopy simulator testing protocol, and the time to completion was again recorded. Both testing protocols involved the simple task of placing a probe on a series of assigned locations in the glenohumeral joint. Spearman rank correlation analysis was performed, and regression analysis was used to determine the predictive ability of the simulator score.

Results: The performance time on the simulation program was strongly correlated with the performance time on the cadaveric model ($r = 0.736$, $p < 0.001$). The time required to complete the simulator task was a significant predictor of the time required to complete the cadaveric task ($t = 4.48$, $p < 0.001$).

Conclusions: These results demonstrated a strong correlation between performance of basic arthroscopic tasks in a simulator model and performance of the same tasks in a cadaveric model.

Clinical Relevance: This study suggests that performance of basic arthroscopic tasks in a simulator environment may be indicative of performance of similar arthroscopic tasks in a surgical setting. This work supports the continued study of arthroscopy simulators as a potentially beneficial educational tool.

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Arthroscopy is one of the most commonly performed orthopaedic procedures in the United States[1]. However, the performance of arthroscopy requires substantial technical skill that can be difficult to obtain in a traditional surgical training environment. Arthroscopic dexterity skills are neither easily nor quickly acquired, and their development may occur at the cost of increased operative times, higher complication rates, and a greater risk of iatrogenic injury to the patient[2,3]. The specialty of orthopaedic surgery is oriented toward performing complex arthroscopic tasks, yet it relies on a nonstandardized and potentially inefficient traditional apprenticeship model to impart these skills to residents[4].

The need for trainees to acquire initial arthroscopic experience outside of the operating room has traditionally been addressed through cadaveric arthroscopic training, which is both costly and labor-intensive. The recent development of arthroscopic simulators holds promise for facilitating arthroscopic training and skills acquisition in a controlled and safe environment[4]. Additionally, the skill levels of the surgical trainee can be quantitatively assessed, and the complexity of the surgical simulation can be adjusted to the needs of the trainee. Prior studies of arthroscopic and endoscopic simulator training have demonstrated validity[4-15]; however, to our knowledge the correlation between arthroscopic task performance on a simulator and during actual surgical procedures has not been previously characterized.

The goal of the current investigation was to evaluate the correlation between performance of tasks in an arthroscopic simulator and in a cadaveric model. We hypothesized that performance of the tasks in the simulator model would positively correlate with task performance in the cadaveric model.

Materials and Methods

Participants

After obtaining institutional investigational review board approval, subjects were recruited from among the residents and attending surgeons in an orthopaedic surgery residency program. All residents were encouraged to participate, regardless of their level of experience in arthroscopy. Attending surgeons who routinely performed arthroscopic procedures were also recruited. Demographic data were collected, including surgical experience, sex, and age. Participants were also surveyed regarding handedness and video game experience, as these have been shown to influence performance in endoscopic simulations[16]. Video game experience was categorized as either limited (none or minimal) or extensive (at least once per month)[16].

Simulator

Simulations were conducted in the simulator center of a research laboratory. The simulator used was the Insight Arthro VR (Immersion, San Jose, California), which uses a realistic life-size simulation of a human shoulder and two robotic arms that grasp the arthroscopic tools (Fig. 1). The system was equipped with a high-definition computer monitor and had an adjustable table height to replicate the environment of the operating room. The robotic arms provide tactile feedback from the arthroscopic tools within the shoulder, allowing the sense of realistic probing and shaving. For the purpose of this study, the system's "Blue Sphere" program was used. In this simulator model, blue spheres appear at random anatomically important locations within the joint. Once the subject touches the sphere with a probe, the sphere disappears and another reappears at a different location within the joint. A sequence of eleven spheres was used to test the simulator performance of each subject. The basic Blue Sphere program was selected because it provided a reproducible testing protocol and could be reproduced in a cadaveric model. This testing program is similar to the program that was used by Gomoll et al.[5].

Fig. 1

Photograph showing the arthroscopic simulator used in the study.

This simulator testing program meets the five critical criteria of realistic simulation described by Satava: fidelity, objective properties, interactivity, sensory input, and reactivity[17]. Fidelity indicates that the image has adequate resolution to appear real. A simulation has appropriate objective properties if the objects perform as they would in the human body (responding to grasping, gravity, etc.). Interactivity indicates that the simulation depicts an accurate representation of the surgeon's instruments as they are being controlled. Sensory input refers to the haptic feedback in the surgeon's hand that results from the events occurring in the simulated environment. Reactivity indicates an accurate response by the tissues that are being handled or cut (e.g., bleeding, deforming, etc.)[17].

Each participant was provided with a two-minute hands-on tutorial regarding use of the simulator, during which the subject was able to navigate through the Blue Sphere program. In addition, the study objectives and scoring system were reviewed during this tutorial session. This tutorial was followed by five minutes of free-practice arthroscopy time on the simulator. Each subject could adjust the height of the table and the angle of the monitor during this time. The simulator's Blue Sphere program was then initiated at the subject's command. The subject was evaluated on the basis of the number of seconds taken to complete the program, as measured by the simulator. Each subject performed three repetitions of the Blue Sphere program, and the time to completion was averaged. The subject was not given a score or objective feedback regarding his or her performance until the testing was completed.

Cadaveric Model

Testing on the cadaveric model was performed at least two weeks after the simulator testing. The cadaveric model was constructed to replicate the simulator and its anatomic targeting challenges, and it contained the same standard anterior and posterior arthroscopic portals as the simulator. The same cadaveric shoulder, from an adult man, was used for each subject. Knots in colored nylon sutures served as the targets, and arthroscopic techniques were used to place these targets at the same anatomic locations as those indicated by the blue spheres in the simulator. A standard 30° large-joint arthroscope and arthroscopy tower were used for all procedures. In order to preserve the cadaver and thus minimize variability, all arthroscopy was performed in a dry environment during a single day.

Subjects were provided with two minutes of instruction followed by five minutes of free-practice arthroscopy time to familiarize themselves with the equipment. Tests were administered by a single proctor (K.D.M.) who was blinded to the results from the arthroscopic simulator. At the start of the exercise, the subject was given an anatomic target to touch with the probe tip. As soon as the test proctor confirmed contact, the subject was given another anatomic target. This process was repeated until all eleven of the anatomic locations tested on the simulator had also been tested on the cadaver. Each subject was evaluated on the basis of the time required to complete the exercise, as measured with a stopwatch. Since the accuracy of instrument handling during the cadaveric testing could not be measured, accuracy could not be compared between the two testing models. We thus compared only the time to completion, which was the only metric available for both testing models. The time to complete a task using a simulator model has been shown to correlate with prior surgical experience[5,18].

Statistical Analysis

The Spearman rank correlation coefficient was used to analyze the primary study objective, the correlation between simulator and cadaveric task performance. In addition, a regression analysis was performed to determine whether performance on the simulator was predictive of performance on the cadaveric model. The effect of the level of clinical experience was analyzed by classifying the attending surgeons as an expert group and the residents as a novice group. The time to completion was compared between these groups for both the simulation and the cadaveric model with use of a standard Student t test. All statistical calculations were performed with use of SAS software (version 9.2; SAS Institute, Cary, North Carolina), and a p value of <0.05 was considered significant for all analyses.

TABLE I Demographic Data for the Expert and Novice Groups

Parameter	Expert	Novice
Age* *(yr)*	37.0 (32-44)	31.3 (26-38)
Sex (male:female)	4:0	13:2
Handedness (right:left:ambidextrous)	4:0:0	12:2:1
Video game experience (novice:experienced)	4:0	10:5

*The values are given as the mean, with the range in parentheses.

Source of Funding

This investigation received no external funding.

Results

All nineteen residents and seven full-time faculty who were present at the time of the study were invited to participate. Nineteen subjects, including fifteen residents and four attending surgeons, agreed to do so. Demographic data for these subjects are shown in Table I.

The expert group consisted of four men ranging from thirty-two to forty-four years of age, and the novice group consisted of thirteen men and two women ranging from twenty-six to thirty-eight years of age. The difference in mean age between the expert and the novice group was 5.7 years.

The task performance time on the simulator correlated strongly with the performance time on the cadaveric model ($r = 0.736$, $p < 0.001$), as shown in the scatter plot in Figure 2.

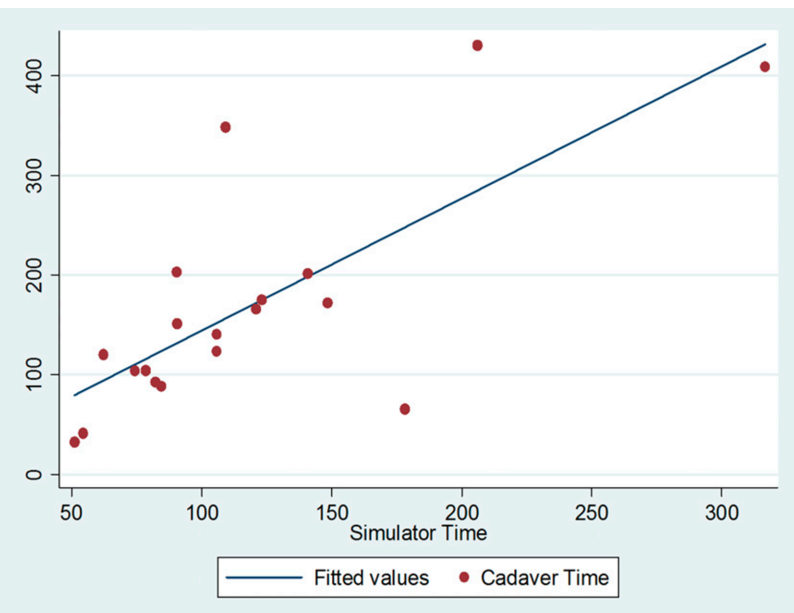

Fig. 2

Scatter plot comparing the completion time in seconds for the cadaveric test (vertical axis) with the completion time in seconds for the simulator test. The best-fit regression line is also shown.

The time required to complete the simulator task was a significant predictor of the time required to complete the cadaveric task ($t = 4.48$, $p < 0.001$).

The expert group completed both the simulator task program and the cadaveric task program significantly faster than the novices did. The mean time (and standard deviation) required by the expert group to complete the simulator task (71.4 seconds) was 57.7 ± 21.0 seconds faster than the time required by the novices (129.1 seconds, $p = 0.016$). Similarly, the mean time required by the expert group to complete the cadaveric task (79.4 seconds) was 110.5 ± 39.4 seconds faster than the time required by the novices (189.9 seconds, $p = 0.016$).

Although five of the subjects in the novice group reported video game experience, we were unable to demonstrate a significant correlation between video game use and performance of either arthroscopic task. The role of sex and hand dominance could not be assessed because of the limited sample size.

Discussion

The purpose of this investigation was to determine whether task performance time on an arthroscopic shoulder simulator would correlate with task performance time on a cadaveric shoulder model. We demonstrated a strong correlation, and we further demonstrated that task performance time on the simulator was predictive of performance time on the cadaveric model. We also confirmed that the time to completion of the arthroscopic simulator program was faster for the surgeons with more clinical experience, as has been shown in previous studies[5-7,15]. However, to our knowledge the current study is the first to demonstrate a correlation between arthroscopic task performance in a simulator model and in a cadaveric model.

The traditional educational adjunct for arthroscopy trainees has involved cadaveric models, which are associated with substantial financial costs and set-up requirements. However, the continued improvement in arthroscopic simulator technology may hold promise for the education of orthopaedic residents. To date, although training on the static ALEX shoulder model has been reported to provide some benefit[19], the transfer of arthroscopic skills from simulator training to clinical practice has still not been demonstrated scientifically to our knowledge. Although the cadaveric testing program that we used is not identical to the performance of shoulder arthroscopy in a patient, it may represent an incremental step between the simulation laboratory and the operating room. Our testing model, which required the placement of a probe on a series of spheres that appeared within the glenohumeral joint, was similar to that used by Gomoll et al.[5]. Although this still represents a basic arthroscopic task, our results suggest that the continued study of arthroscopic simulation technology and applications may demonstrate the usefulness of such simulators for the arthroscopic training of orthopaedic surgeons.

Our study has several limitations, including the small sample size and potential selection bias among our cohort. The small number of subjects did not allow for meaningful analysis of the effect of variables such as sex and video game experience. A further limitation is that performance in the cadaveric model was determined solely by the time required for task completion. Although one study has challenged whether task completion time on a simulator is commensurate with arthroscopic skill[20], other studies have shown that time to completion of arthroscopic tasks does correlate with surgical experience[5,18]. The arthroscopic simulator did measure accuracy of movement in addition to time to completion, but we were not able to measure these parameters in the cadaveric model and a comparison was therefore not possible. A final limitation involves the cadaveric model utilized in this study. Although the cadaveric testing program was designed to mimic the simulator testing program and thus minimize differences between the two testing protocols, it could not fully evaluate the complex set of neuromotor tasks involved in arthroscopic shoulder surgery in a clinical setting. The performance of timed arthroscopic tasks in either a simulated environment or a cadaveric model is not the same as the performance of actual arthroscopic surgery. We also elected to perform the arthroscopy in a dry environment to minimize variability resulting from changes in the single specimen that was used by the entire study cohort. Although the visualization remained good throughout the study and the addition of saline solution to the test environment was not missed by the study subjects, this is yet another aspect that differed between our testing scenario and a clinical one.

Despite these limitations, the information presented here provides insight into the contribution of training and surgical experience to the development of arthroscopic skills. Our selected simulator and cadaveric models required and tested an understanding of complex three-dimensional anatomy as well as the hand-eye coordination that is necessary to triangulate within the glenohumeral joint. Each of these models may represent a reasonable surrogate that can be used for acquiring the basic arthroscopic skills required for the performance of arthroscopy in a surgical setting. The simple nature of our chosen testing protocols allowed for the control of potential confounding factors and for accurate analysis of our chosen variable—a necessary initial step in demonstrating the utility of simulator use.

A previous evaluation of simulator training for airline pilots indicated that increasing age was associated with a decline in overall simulator performance[21]. Subject age thus has the potential to confound studies of simulator use that involve both orthopaedic residents and attending surgeons, as these two groups often differ substantially in age. In our study, the mean age of the attending surgeons was only 5.7 years greater than that of the residents, which may be due primarily to performance of the study at a military orthopaedic surgery residency program where attending faculty tend to be relatively young. Consequently, the potential confounding effect of age-related reduction in reaction time would have been minimized in our study.

In conclusion, this study has provided insights into the role of training and surgical experience in the development of arthroscopic skills. A strong correlation was observed between arthroscopic task performance in simulator and cadaveric models. The results of this study may help to facilitate the development and implementation of standardized simulator training in orthopaedic resident education. Such standardized simulator training may allow orthopaedic surgery residency programs to accelerate residents' acquisition of basic neuromotor skills required in arthroscopy while minimizing the increased operative times and potential iatrogenic injury to patients that are associated with the learning of such skills during actual surgical procedures.

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