Computer-Simulated Arthroscopic Knee Surgery: Effects of Distraction on Resident Performance

JAMES B. COWAN, MD; MARK A. SEELEY, MD; TODD A. IRWIN, MD; MICHELLE S. CAIRD, MD

abstract

Orthopedic surgeons cite “full focus” and “distraction control” as important factors for achieving excellent outcomes. Surgical simulation is a safe and cost-effective way for residents to practice surgical skills, and it is a suitable tool to study the effects of distraction on resident surgical performance. This study investigated the effects of distraction on arthroscopic knee simulator performance among residents at various levels of experience. The authors hypothesized that environmental distractions would negatively affect performance. Twenty-five orthopedic surgery residents performed a diagnostic knee arthroscopy computer simulation according to a checklist of structures to identify and tasks to complete. Participants were evaluated on arthroscopy time, number of chondral injuries, instances of looking down at their hands, and completion of checklist items. Residents repeated this task at least 2 weeks later while simultaneously answering distracting questions. During distracted simulation, the residents had significantly fewer completed checklist items ($P<.02$) compared with the initial simulation. Senior residents completed the initial simulation in less time ($P<.001$), with fewer chondral injuries ($P<.005$) and fewer instances of looking down at their hands ($P<.012$), compared with junior residents. Senior residents also completed 97% of the diagnostic checklist, whereas junior residents completed 89% ($P<.019$). During distracted simulation, senior residents continued to complete tasks more quickly ($P<.006$) and with fewer instances of looking down at their hands ($P<.042$). Residents at all levels appear to be susceptible to the detrimental effects of distraction when performing arthroscopic simulation. Addressing even straightforward questions intraoperatively may affect surgeon performance. [Orthopedics. 2016; 39(2):e240-e245.]

Knee arthroscopy is among the most frequently performed orthopedic operations, and because of its low morbidity, diagnostic utility, and broad therapeutic application, it is a fundamental skill in orthopedic surgery resident education. This procedure requires high levels of cognitive ability, psychomotor coordination, 3-dimensional visuospatial perception from 2-dimensional camera images, and skillful manipulation of equipment within a relatively small space. Learning these skills is time consuming, and doing so in the operating room increases operative time and cost and potentially increases operative complications. Teaching arthroscopy outside of the operating room with cadaveric models, animal models, and manmade models or simulators has been limited because of problems with the availability, expense, and/or realism of these options. As surgical training moves toward a competency-based model in which residents must demonstrate basic knowledge and...
surgical skills sequentially before promotion, simulator training may become increasingly important. Surgical simulation provides a safe and cost-effective educational environment that allows residents to develop skills to proficiency.\(^{11,12}\) Additionally, acquisition of skills outside of the operating room has become essential because of restricted work hours, patient safety concerns, operative cost, and the increasing number of technically challenging procedures.\(^ {13,14}\) Mabrey et al\(^ {9}\) noted that arthroscopic simulation offers numerous advantages: uniform training scenarios among programs, the ability to record and play back “expert” performances, no risk to patients, the opportunity for residents to practice independently, and the opportunity to avoid the need for costly disposable equipment and operating room time.

Unlike surgical simulation, the operating room exposes residents to numerous distractions, including pages regarding patient care, consultations, conversations unrelated to the surgery, and noise from numerous devices and machines.\(^ {1,8,15-18}\) Although surgeons, nurses, and anesthesia staff may all experience distractions in the operating room, surgeons are the most frequently distracted.\(^ {19}\) Surveyed orthopedic surgeons noted that “full focus” and “distraction control” are important factors for achieving excellent outcomes.\(^ {20}\) Siu et al\(^ {21}\) found that inexperienced individuals performed simulated laparoscopic tasks more slowly and less efficiently in the presence of prerecorded operating room noise, although others reported conflicting results.\(^ {22}\) In a study by Moorthy et al.\(^ {23}\) surgeons performed simulated laparoscopic tasks under various conditions. A significantly greater number of errors occurred under “stress-inducing conditions,” and the effect was more pronounced when multiple stressors were applied simultaneously.

It is unclear to what extent environmental distraction contributes to knee arthroscopic simulator performance. This study used a knee arthroscopy simulator to investigate the effects of distraction on surgical performance among residents at various levels of surgical experience. The authors hypothesized that environmental distractions would negatively affect the performance of arthroscopic knee simulation. Understanding how residents respond to distraction during arthroscopic knee simulation is important to identify the appropriate complexity of educational simulation modules for trainees.

**Materials and Methods**

After institutional review board approval was obtained, 25 orthopedic surgery residents from a single institution were recruited to participate in this study between March and October 2013. The study included all residents other than interns and postgraduate year 2 residents who had not yet completed a rotation on the sports medicine service. “Junior” residents were postgraduate year 2 residents or postgraduate year 3 residents who had participated in 10 or fewer knee arthroscopies. “Senior” residents were postgraduate year 3 residents who had participated in 10 or more knee arthroscopies, postgraduate year 4 residents, and postgraduate year 5 residents. Residents were unaware that the goal of the study was to evaluate the effects of distraction on arthroscopic simulator performance.

This study used the ArthroSim Arthroscopy Simulator (Touch of Life Technologies, Aurora, Colorado), a virtual reality knee arthroscopy simulator with high-fidelity haptic feedback. This simulator was designed in collaboration with the American Academy of Orthopaedic Surgeons, the American Board of Orthopaedic Surgeons, and the Arthroscopy Association of North America.\(^ {24,25}\) The only individuals present during the simulation were the study participant, an assistant, and 1 or 2 study authors who acted as the evaluators. Before evaluation, residents familiarized themselves with the simulator. Each resident was instructed to perform a diagnostic knee arthroscopy according to a posted 15-item checklist based on a checklist designed by Elliott et al\(^ {26}\) (Table 1). The evaluators determined whether each checklist item was adequately completed. Participants were also evaluated on total arthroscopy time, number of chondral injuries as indicated by an audio alert on the simulator, and instances of look-

**Table 1**

<table>
<thead>
<tr>
<th>Arthroscopic Skills Assessment Checklist(^ {2})</th>
</tr>
</thead>
<tbody>
<tr>
<td>Suprapatellar pouch</td>
</tr>
<tr>
<td>View all areas of the pouch</td>
</tr>
<tr>
<td>Patella</td>
</tr>
<tr>
<td>View the medial facet</td>
</tr>
<tr>
<td>View the lateral facets</td>
</tr>
<tr>
<td>Trochlea</td>
</tr>
<tr>
<td>View the trochlear surface</td>
</tr>
<tr>
<td>Medial recess</td>
</tr>
<tr>
<td>View and inspect the anterior cruciate ligament</td>
</tr>
<tr>
<td>View and inspect the posterior cruciate ligament</td>
</tr>
<tr>
<td>Medial compartment</td>
</tr>
<tr>
<td>Assess the condyle for chondral lesions</td>
</tr>
<tr>
<td>View the meniscus (anterior, middle, and posterior)</td>
</tr>
<tr>
<td>Probe the superior and inferior surfaces</td>
</tr>
<tr>
<td>Lateral compartment</td>
</tr>
<tr>
<td>Assess the condyle for chondral lesions</td>
</tr>
<tr>
<td>View the meniscus (anterior, middle, and posterior)</td>
</tr>
<tr>
<td>Probe the superior and inferior surfaces</td>
</tr>
</tbody>
</table>

\( ^{2}\) Evaluators had to check yes or no for each item.
ing down at their hands as counted by an evaluator. Participants were aware of the checklist and knew that they were being timed, but they were not aware of other points on which they were being evaluated. The simulation was considered complete when a participant stated that he or she had completed the diagnostic arthroscopic evaluation.

At a minimum of 2 weeks after the initial simulation, residents repeated this task under similar conditions but while simultaneously answering distracting questions posed by an evaluator. Between 30 and 60 seconds into the distracted simulation, each resident was asked to recite the Schatzker classification for tibia plateau fractures. Between 60 and 90 seconds after this question was answered, each resident was asked to name 5 of the United States with their corresponding capital cities.

Statistical analysis was performed with SPSS version 21 software (IBM, Armonk, New York). Statistical comparisons were made between initial simulation and distracted simulation and between junior residents and senior residents. Categorical data were compared with chi-square tests, and continuous data were compared with Student’s t tests with an applied 5% level of significance.

### RESULTS

#### Initial Simulation Versus Distracted Simulation—All Residents

The study included 14 junior residents and 11 senior residents. During distracted simulation, residents had significantly fewer completed checklist items (12.2 vs 14.0, \(P < .02\)) compared with the initial simulation, but no significant differences were found in arthroscopy time (\(P < .15\)), chondral injuries (\(P < .23\)), or instances of looking down at their hands (\(P < .29\)). These results are summarized in Table 2.

No statistically significant differences were found between initial and distracted simulations among junior residents (Table 3). Senior residents had a significantly increased number of chondral injuries during distracted simulation (\(P < .001\)), but no other statistically significant differences were found between initial and distracted simulations (Table 4). During distracted simulation, junior residents were less likely to thoroughly evaluate the lateral recess (\(P < .04\)), but more likely to thoroughly evaluate the suprapatellar pouch (\(P < .04\)).

#### Initial Simulation—Senior Residents Versus Junior Residents

Senior residents completed the arthroscopic simulation in less time (286.9 seconds vs 581.8 seconds, \(P < .001\)), with fewer chondral injuries (3.5 vs 13.9, \(P < .005\)) and with fewer instances of looking down at their hands (2.5 vs 5.4, \(P < .012\)), compared with junior residents (Table 5).

During the initial simulation, senior residents completed 97% of the diagnostic checklist, whereas junior residents completed 89% (\(P < .019\)). Junior residents were significantly less likely to thoroughly evaluate the suprapatellar pouch compared with senior residents (\(P < .04\)). Both groups had difficulty adequately assessing the trochlear surface, with only 79% of junior residents and 82% of senior residents performing a thorough evaluation. When using the ar-

### Table 2

**Outcomes of Initial and Distracted Simulations for the Entire Cohort**

<table>
<thead>
<tr>
<th>Assessment Variable</th>
<th>Initial Simulation</th>
<th>Distracted Simulation</th>
<th>(P)</th>
<th>Confidence Interval</th>
</tr>
</thead>
<tbody>
<tr>
<td>Time, mean±SD (range), seconds</td>
<td>452.0±245.9 (170-1139)</td>
<td>393.6±200.3 (44-839)</td>
<td>.146</td>
<td>-92.48 to 270.48</td>
</tr>
<tr>
<td>Chondral injuries, mean±SD, No.</td>
<td>9.3±9.7</td>
<td>11.3±7.4</td>
<td>.229</td>
<td></td>
</tr>
<tr>
<td>Look-downs, mean±SD, No.</td>
<td>4.1±3.0</td>
<td>4.6±2.9</td>
<td>.286</td>
<td></td>
</tr>
<tr>
<td>Completed checklist items, mean±SD, No.</td>
<td>14.0±1.4</td>
<td>12.2±3.1</td>
<td>.017</td>
<td></td>
</tr>
<tr>
<td>Schatzker classification, correct</td>
<td>N/A</td>
<td>85.3%</td>
<td>N/A</td>
<td></td>
</tr>
<tr>
<td>State capitals, correct</td>
<td>N/A</td>
<td>92.8%</td>
<td>N/A</td>
<td></td>
</tr>
</tbody>
</table>

*Abbreviation: N/A, not applicable.*

### Table 3

**Outcomes of Initial and Distracted Simulations for Junior Residents (n=14)**

<table>
<thead>
<tr>
<th>Assessment Variable</th>
<th>Initial Simulation</th>
<th>Distracted Simulation</th>
<th>(P)</th>
<th>Confidence Interval</th>
</tr>
</thead>
<tbody>
<tr>
<td>Time, mean±SD (range), seconds</td>
<td>581.8±259.9 (266-1139)</td>
<td>492.8±203.9 (44-839)</td>
<td>.32</td>
<td>-92.48 to 270.48</td>
</tr>
<tr>
<td>Chondral injuries, mean±SD, No.</td>
<td>13.9±11.0</td>
<td>13.9±8.8</td>
<td>1.00</td>
<td>-7.74 to 7.74</td>
</tr>
<tr>
<td>Look-downs, mean±SD, No.</td>
<td>5.4±3.4</td>
<td>5.6±3.5</td>
<td>.88</td>
<td>-2.88 to -2.48</td>
</tr>
<tr>
<td>Completed checklist items, mean±SD, No.</td>
<td>13.4±1.6</td>
<td>11.8±3.0</td>
<td>.09</td>
<td>-0.27 to 3.47</td>
</tr>
<tr>
<td>Schatzker classification, correct</td>
<td>N/A</td>
<td>82.1%</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>State capitals, correct</td>
<td>N/A</td>
<td>90.0%</td>
<td>N/A</td>
<td>N/A</td>
</tr>
</tbody>
</table>

*Abbreviation: N/A, not applicable.*
throscopic probe to assess the femoral condyles, junior residents performed an inadequate examination more often than senior residents, although this difference was not statistically significant.

**Distracted Simulation—Senior Residents Versus Junior Residents**

During distracted simulation, senior residents continued to perform the arthroscopic simulation more quickly (267.3 seconds vs 492.8 seconds, \( P<.003 \)) and with fewer instances of looking down at their hands (3.3 vs 5.6, \( P<.042 \)), but no significant difference was found in chondral injuries (\( P<.052 \)) or completed checklist items (\( P<.381 \)) compared with junior residents. No significant difference was found between senior and junior residents in the percentage of correct responses to the questions about the Schatzker classification (\( P<.529 \)) and state capitals (\( P<.458 \)) (Table 6).

There was no significant difference between the percentages of junior and senior residents who adequately evaluated each checklist item during distracted simulation. Both groups of residents inadequately examined the popliteus and the medial and lateral femoral condyles with the arthroscopic probe during distracted simulation.

**DISCUSSION**

During distracted simulation, residents had significantly more missed checklist items. They also had a greater number of chondral injuries and more instances of looking down at their hands, and they completed the simulation more quickly, although these differences were not significant. This increased speed may have been the result of the simulator learning curve or the additional arthroscopic experience gained between simulations. It also may have been caused by omission of critical tasks or frustration caused by the distracting questions, either of which could have detrimental effects in real operative cases. Although most residents answered the distracting questions correctly, their performance was affected nonetheless. This suggests that it may not be the extent of the distraction but rather the occurrence of any distraction at all that is important. Additionally, although the content of the responses was inconsequential in this study, in clinical situations, where distracting
questions may be related to patient care, the content of the answers is critical.

As expected, senior residents showed greater arthroscopic proficiency at baseline compared with junior residents. However, residents at all levels appear to be susceptible to the effects of distraction when performing arthroscopic simulation. During distracted simulation, although senior residents continued to work more quickly and with fewer instances of looking down at their hands compared with junior residents, no significant differences were found between the cohorts in the number of chondral injuries or the percentage of checklist items completed.

Studies have shown that surgical simulators can discriminate between novice and experienced participants. Arthroscopists with more experience show increased speed, more efficient path of instrument use, and fewer instrument collisions, and they also use less force, apply more even force when shaving or burring, and show more consistent performance on arthroscopy simulators. Martin et al. found that arthroscopic shoulder simulator performance correlated most strongly with postgraduate year in training and the number of shoulder arthroscopies performed. Gomoll et al. reported that groups with similar arthroscopic experience showed similar speed, number of instrument collisions, and instrument distance traveled during simulation. Despite these findings, the issue of “transfer validity”—whether surgical skills practiced or acquired during simulation exercises truly affect operating room performance—is an aspect of simulation education that requires further study. Howells et al. found that orthopedic surgery trainees who received arthroscopic simulator training performed significantly better on an intraoperative procedure-based assessment than those who did not receive this training. There are conflicting reports in the literature on the extent and duration of the benefits derived from simulation training.

The subjective educational value of simulator training has also been studied. Although operative participation and observation may be the most-valued educational resource for orthopedic training, arthroscopic skills laboratories offer valuable opportunities to practice triangulation skills and develop familiarity with surgical equipment. Hui et al. found that arthroscopic simulation was highly valued by residents for identification of anatomic structures, arthroscopic navigation, triangulation, and precise portal placement. Despite these benefits, there are areas for improvement because certain aspects of arthroscopy simulation, such as tissue probing, have been described as unrealistic.

The limitations of the current study include a relatively small sample size, inclusion of participants from a single residency program, and inability to blind evaluators to whether participants were being distracted. In addition, the study did not account for the simulator learning curve or operative experience between the 2 simulation trials. Residents who completed the distracted simulation were asked not to divulge the purpose of the study to residents who had not completed the study. However, the authors could not be certain that all subsequent participants were unaware that they would be asked distracting questions or even what questions they would be asked during the distracted simulation. In clinical scenarios, simulated pages from a nurse or the emergency department or recorded noise from an operating room may provide a more realistic distraction. However, the authors used questions with unambiguous answers to facilitate quantifying the number of correct and incorrect answers. In future studies, it may be useful to use more clinically relevant or realistic distractions. Given the frequency with which knee arthroscopy is therapeutic as well as diagnostic, it also may have been more realistic to have residents perform therapeutic arthroscopic tasks as opposed to only diagnostic tasks. Finally, as with any study on surgical simulation, the training environment does not completely replicate the actual operative experience, so results must be extrapolated with caution.

CONCLUSION

It is impossible to anticipate or eliminate all intraoperative distractions, but this study suggests that addressing even straightforward questions intraoperatively may affect surgeon performance. Additional studies are needed to further investigate the utility of arthroscopic simulation, the ability of surgeons to address complex clinical questions intraoperatively, and the behaviors and responses of surgeons who are least susceptible to the effects of distraction. As the role of surgical simulation in resident education expands, it will be important to develop training modules that recreate the intraoperative environment and maximize transfer validity. Intraoperative distractions should not be accepted as inevitable, and strategies to minimize them must be investigated. However, it is also necessary to create realistic training environments that allow residents to practice their skills to proficiency.

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