Low-Fidelity Simulation: An Emerging Trend in Orthopaedic Surgical Education

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Introduction

Current and future surgical residents face a vastly different learning environment than those of previous generations. While the number and complexity of required surgical skills continues to increase, institutional changes such as work-hour restrictions, heightened emphasis on patient safety, and efforts to improve efficiency to reduce health-care costs pose challenges to learning in the operating room (OR).[1,2] In response, many surgical residency programs have developed innovative methods to teach surgical skills in non-traditional venues. Simulation training offers residents the opportunity to acquire and practice skills in a learner-centric environment. Its favorability among orthopaedic teachers and trainees is demonstrated by a 2013 national survey reporting that 86% of orthopaedic surgery residents and 80% of program directors agreed that surgical skills simulations should become a required part of training.[3] Yet, 87% of program directors identified a lack of available funding as the most substantial barrier to developing such programs at their institutions. Nonetheless, both the American Board of Orthopaedic Surgery (ABOS) and the Accreditation Council for Graduate Medical Education (ACGME) have mandated use of surgical simulation in orthopaedic residency curricula.[4]

Benefits of Simulation Training

Simulation training has improved operative performance of trainees in a variety of surgical disciplines.[5-9] Moreover, whereas evaluation of resident performance can be difficult in the operating room setting, simulation training allows instructors to prioritize resident learning and focus on evaluating and teaching specific components of complex procedures. Deliberate practice in a simulation setting may be a more efficient teaching modality than experience alone, especially for learning basic psychomotor skills.

Development of technical skills in an ex-vivo setting can lead to a synergistic improvement in trainees' intraoperative educational experience. In a randomized trial, Palter et al[10] demonstrated that residents trained in fascial closure on a low-fidelity simulator not only exhibited better technical skills in the OR, but performed better on an examination of clinical material discussed during the case. These findings are consistent with the Fitts-Posner theory of motor skills acquisition, which proposes that novice learners must devote more active attention to performing tasks. In contrast, trainees proficient in basic surgical skills have sufficient cognitive attention to devote to simultaneously learn surgical decision-making, a critical component of surgical training that is less amenable to learning outside of the OR.[11-13]

Low-Fidelity Simulation: Goals and Challenges

In light of such benefits, surgical simulation technology, and associated costs, have grown rapidly in recent years. For example, Blyth et al[14] developed computerized simulators in which learners perform hip fracture fixation in a three-dimensional virtual environment. In contrast to the realism depicted in such a high-fidelity virtual reality program, low-fidelity simulation aims to develop interventions that incorporate essential elements of a surgical skill into a cost-effective model that can be replicated and implemented in a wide variety of training environments.[9] Low-fidelity interventions are rooted in educational theory, which suggests that fidelity is less relevant for novice learners.[15] Therefore, low-fidelity interventions are best targeted for junior trainees to develop basic psychomotor skills or to learn the sequence of multi-step procedures.

In developing and validating a low-fidelity simulation tool, it is critical to establish a direct relationship between a learner's proficiency using the low-fidelity tool and improvement in the analogous intraoperative skill. For example, while Butler et al[16] successfully trained medical students to perform a diagnostic knee arthroscopy on an anatomic dry model, this skillset did not translate significantly into improved proficiency for knee arthroscopy in cadaver specimens. The authors concluded that the model could supplement, but not replace the cadaveric specimens. Ultimately, researchers in surgical education are challenged to correlate simulation training with improved patient outcomes.

Recent Advancements

Although orthopaedic surgery has lagged behind other surgical disciplines in developing simulation tools, recent guidelines have spurred interest in the field, as evidenced by three studies published in 2015.

Lopez et al[17] created the Fundamentals of Orthopaedic Surgery (FORS) board (Figure 1), which trains junior-level residents in six skills, including fracture reduction, three-dimensional drilling accuracy, simulated fluoroscopy-guided drill accuracy, depth-of-plunge minimization, drill-by-feel accuracy, and suturing. The FORS board is composed of supplies purchased at a local hardware store for a cost of less than $350. After longitudinal training using the FORS board, a group of 25 medical students outperformed a control group of junior residents in four of the six skills.

Similarly, Coughlin et al[18] developed and validated a simple box model for training and evaluating learners on specific fundamental psychomotor skills of arthroscopy (Figure 2). The study demonstrated that increased level of experience correlated with improved performance in probing, grasping, tissue resection, shaving, suture-passing, and knot-tying. High intra-rater and inter-rater reliability, evidenced by an intraclass correlation coefficient of 0.99, supports the model's use as a learner assessment tool.

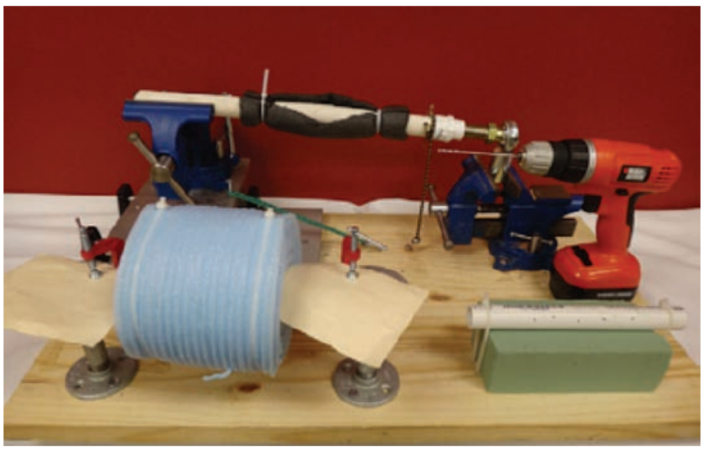

Figure 1. The Fundamentals of Orthopaedic Surgery (FORS) Board.

[Re-printed with permission from Lopez G, et al. A cost-effective junior resident training and assessment simulator for orthopaedic surgical skills via fundamentals of orthopaedic surgery: AAOS exhibit selection. *J Bone Joint Surg Am.* 2015;97(8):659-666.]

Dedicated time for simulation offers a training ground not only for learners, but also for teachers, as coaching strategies can be designed and validated in this setting. In a randomized trial, Levy et al[19] compared two modalities for teaching two different basic surgical skills: tying a locking, sliding knot and making a low-angle drill hole. In comparison to the learners taught by demonstration alone, those receiving real-time acoustic feedback under operant learning principles demonstrated significantly greater precision in both surgical tasks. Taken together, these studies suggest an emerging interest in leveraging simulation resources for researching educational initiatives.

Future Directions

The University of Pennsylvania is well-suited to be at the forefront of this emerging field. The Human Tissue Lab (HTL) has served as an exemplary model for integrating surgical skills instruction into an orthopaedic residency curriculum. With routine, frequent time devoted to resident education already established in this state-of-the-art facility, Penn can serve as a model program for developing and testing simulation interventions. As one example, a randomized trial that compares two modalities for teaching ACL graft preparation is planned for a resident teaching session in HTL in 2016. In addition, a low-fidelity model to teach the skill of pin placement when drilling a convex surface, simulating an osteochondral lesion, is also in development. Such work promotes the development of orthopaedic surgery trainees amidst a new learning environment.

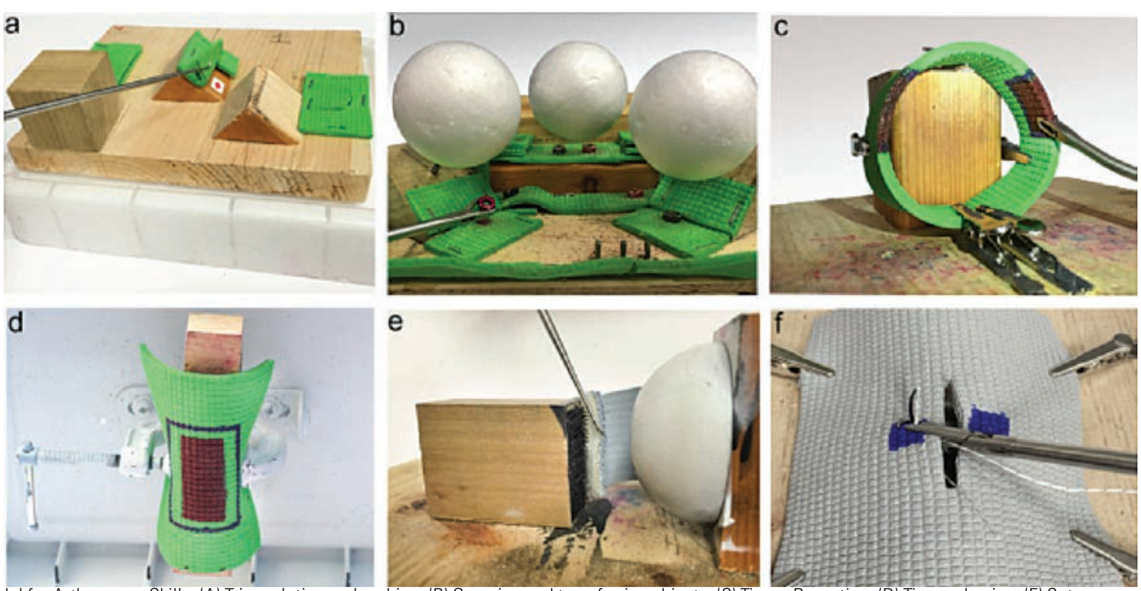

Figure 2. Box Model for Arthroscopy Skills. (A) Triangulation and probing. (B) Grasping and transferring objects. (C) Tissue Resection. (D) Tissue shaving. (E) Suture-passing. (F) Arthroscopic knot-tying.

[Re-printed with permission from Coughlin RP, et al. A validated orthopaedic surgical simulation model for training and evaluation of basic arthroscopic skills. *J Bone Joint Surg Am.* 2015;97(17):1465-1471.]

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