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Construct Validity, Assessment of the Learning Curve, and Experience of Using a Low-Cost Arthroscopic Surgical Simulator

Henry B. Colaco, Colaço, MSc, FRCS (Tr&Orth) MFSTEd, Katie Hughes, BSc (Hons), Eyiyemi Pearse, MA, FRCS (Orth), Magnus Arnander, MSc, FRCS (Orth), and Duncan Tennent, FRCS (Orth), PgCert (MedEd), MAcadMEd, FFSTEd

St George's University of London, London, UK

OBJECTIVE: We have developed a low-cost, portable shoulder simulator designed to train basic arthroscopic skills. This study aimed to establish the construct validity of the simulator by determining which parameters discriminated between experience levels and to assess the experience of using the simulator.

DESIGN: Participants were given an introductory presentation and an untimed practice run of a 6-step triangulation task using hooks and rubber bands. A total of 6 consecutive attempts at the task were timed, and the number of times the participant looked at their hands during the task was recorded. Participants then completed a questionnaire on their experience of using the simulator.

SETTING: St George's Hospital, London and the South West London Elective Orthopaedic Centre, Surrey.

PARTICIPANTS: Medical students, trainee doctors and surgeons, and consultant surgeons were approached to use the simulator. Participation was voluntary and nonincentivized. In total, 7 orthopedic consultants, 12 trainee doctors (ranging from foundation year 1 to clinical fellow post-Certificate of Completion of Training), and 9 medical students were recruited.

RESULTS: The average time for medical students to complete the task was 161 seconds, compared to 118 seconds for trainees, and 84 seconds for consultants. The average fastest time for medical students was 105 seconds, 73 seconds for trainees, and 52 seconds for consultants. Students were significantly slower than trainees ($p = 0.026$) and consultants ($p = 0.001$). However, times did not differ significantly between trainees and consultants. Consultants looked at their hands 0.7 times on average during the task compared with 2.8 and 3.4 times for trainees and students, respectively. More than 95% of participants found the exercise interesting and agreed or strongly agreed that the simulator was easy to use, easily portable, and well designed and constructed.

DISCUSSION: This study has established construct validity of the simulator by demonstrating the ability to distinguish between surgical experience levels. The learning curve shows improvement in individuals with or without arthroscopic or surgical experience. Simulation is becoming increasingly important in the training of medical students and surgical trainees; this study has established that low-cost portable arthroscopic box trainers may play a significant role. (J Surg Ed ■:■■■-■■■. © 2016 Association of Program Directors in Surgery. Published by Elsevier Inc. All rights reserved.)

KEY WORDS: simulation, arthroscopy, surgery, training

COMPETENCY: Practice-Based Learning and Improvement

Correspondence: Inquiries to Katie Hughes, BSc, St George's University of London, Cranmer Terrace, London, UK; E-mail: katiephughes@gmail.com, m0900432@sgul.ac.uk

INTRODUCTION

Arthroscopy has become an integral part of the surgical workload within trauma and orthopedics. However, it is a challenging skill to learn which requires manual dexterity, spatial awareness, and accurate manipulation of arthroscopic instruments. Restrictions in working hours in Europe and the United States limit the time trainees are able to spend observing and undertaking arthroscopic procedures in the operating theater.[1-3] Subsequently, development of these skills may come at a cost of increased operating times, higher complication rates, and inferior surgical outcomes for patients.[4,5] Given this, there is clearly a need for trainees to develop their arthroscopic skills outside the theater environment. Simulation in arthroscopic surgical training has been shown to shorten the learning curve, reduce errors in live surgery, and improve patient outcomes.[6] Simulators also

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facilitate the safe practice of visualization, triangulation, and feedback skills for trainees.[7] Simulation is becoming established as an integral part of modern surgical training in orthopedics and across other surgical specialties.[8-11]

There are numerous surgical simulation systems currently available, ranging from simple box trainers to highly advanced virtual reality systems. However, their availability is limited and they can be expensive to purchase and maintain with prices ranging from £350 to £140,000 GBP ($500-$200,000 USD).[12] Although basic box trainers remain an effective, low-cost training tool—they often require specific equipment or operating displays that limit their application and availability.[12] Given this, there appears to be a gap in the market for an inexpensive, widely available, portable arthroscopic simulator. Aslam et al.[13] have successfully constructed a homemade laparoscopic simulator, but a similar arthroscopic-specific trainer is yet to have been described in the literature.

We have designed and constructed a novel box trainer designed to learn basic arthroscopic triangulation skills. It can be assembled from widely available inexpensive materials. It is light, easily portable, and can be taken apart and reassembled in a matter of seconds.

Before a surgical simulator can be used to train surgeons or to assess skills, it must be assessed for construct validity. Construct validity is the degree to which a training tool is able to distinguish between experience levels of the user. More experienced individuals would be expected to score higher than novices—reflecting their true surgical ability when performing an actual procedure.[14-17] We hypothesized that the triangulation task would be able to distinguish between experience levels. We also aimed to assess the learning curve of the task and the experience of using the simulator.

MATERIALS AND METHODS

Apparatus

The simulator was constructed from a 0.7-L translucent blue polypropylene box (155 mm long × 100 mm wide x 80 mm high), with a removable lid (Really Useful Products Ltd., W. Yorks, UK). A total of 7 access portals were drilled using a 20-mm spade-tipped drill bit, and sealed with 23.7-mm flexible silicone sealing grommets (Maplin Electronics, S. Yorks, UK). The portals were located to replicate posterior (P), lateral (L), superolateral (SL), high anterior (HA), low anterior (LA), and Neviaser (N) portals commonly used in shoulder arthroscopy. By rotating the lid, the box can be used to represent both right and left shoulders; and adhesive-backed hook and loop tape strips in the base allow for different inserts to be secured. The box itself is secured to a rubber-backed medium-density fiberboard base with adhesive hook and loop tape, which allows fixation to a tabletop using an adjustable clamp. The inside of the box is viewed using a handheld Supereyes 2.0 megapixel Y002, 7-mm diameter 0° USB-powered "pencil" scope with 4 LED light source (Shenzhen D&F Co., Shenzhen, China) and free trial access "miXscope" digital microscope software (EdH Software LLC, Boise, ID) on an Apple MacBook Pro (Apple, Cupertino, CA). A donated DePuy Mitek suture manipulator (DePuy Synthes, West Chester, PA), 3-hinged Command kitchen utensil hooks (3M, St Paul, MN), and colored elastic bands were used to complete the triangulation task. The total cost of assembly was less than £50 ($72 USD) (Table 1). Photographs of the exterior, interior, and fully assembled box simulator are shown in Figures 1 to 4.

TABLE 1. Simulator Component Cost. Currency Conversions Made in May 2016

2-Pack 0.7-L really useful box	£2.99/$4.30
USB-powered 0° "pencil" scope	£34.69/$50.50
10-Pack 23.7-mm cable grommets	£3.59/$5.00
Command kitchen utensil hooks	£2.50/$3.60
MDF board	£1.95/$2.80
Clamp	£1.78/$2.50
Colored elastic bands	£1.62/$2.30
Total	£49.12/$70.88

MDF, medium-density fiberboard.

Task and Assessment

Participants were first given an introductory presentation on the box simulator and given a "trial run" to familarize themselves with the box and the scope field of view. They had the opportunity to ask any questions about the box or the task. They were then guided through a 6-step abstract triangulation task using the suture manipulator, elastic bands, and hinged utensil hooks. Participants were allowed an untimed practice attempt before being asked to complete 6 consecutive timed attempts. An observer timed the task using a stopwatch from the moment the suture manipulator was first introduced to the box to the moment the last hook was flipped into its final position.

The task involved first flipping the 3 utensil hooks toward the center of the box using the suture manipulator via the SL portal, introducing a rubber band to the box via the LA portal, using the L portal to hook the rubber band around the 3 hooks, unhook and remove the band using the LA portal, and finally return the hooks to their starting position again via the SL portal.

As the box simulator is semiopaque, it is possible to view the inside of the box and watch the training task under direct vision. Participants were instructed to not look at their hands or the box during the task apart from when introducing the suture manipulator through a portal, but were not informed that this was recorded as a secondary outcome measure. The total time of each task attempt and