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AN INTERNATIONAL MULTI-PROFESSIONAL MEETING
CHICAGO, IL
MARCH 15-16, 2019

SCIENTIFIC ABSTRACTS
PAPERS SESSION I
FRIDAY, MARCH 15, 2019
Expansion of Surgical Simulation Through the Development of Economic Laparoscopic Simulators and Student-run Organizations

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INTRODUCTION: Surgical simulation exercises have proven paramount in the development of fundamental surgical skills outside of the operating room. Not only has early-implementation of simulation been associated with increased interest, but compared to institutional use alone, personal-use laparoscopic simulators have shown to significantly enhance skill proficiency. Affordable access to simulation equipment, however, remains a primary obstacle in the advancement of the field. The aim of this project was to create a standard economic, portable laparoscopic simulator using low-cost materials and assessing its impact on medical student skills progression through a student-run organization.

METHODS: Laparoscopic simulator kits were designed through the collaboration of surgical trainees and engineers specialized in low-cost materials using Computer Aided Design (CAD) software and produced from corrugated material with rubber lining, a USB high-speed (60fps) video camera, and two forceps. Pre-clinical students attending Meharry Medical College were invited to participate in this pilot study assessing a series of modified McGill Inanimate System for Training and Evaluation of Laparoscopic Skills (MISTLES) curriculum over the course of five weeks.

RESULTS: The proposed economic design cost 65% less than the most comparable unit on the market. This presents a $6,300 reduction in cost when supplying a student organization, residency program, or outreach endeavor with 20 units. The demographics characterizing the 17 participants in the early stages of this pilot study are Table 1. By the completion of the study, there is expected to be over 50 participants.

CONCLUSIONS: The development of standardized economic laparoscopic simulator kits through multi-professional collaboration may be an effective means of overcoming cost limitations in the expansion of surgical education towards not only trainee personal-use, but also to low and middle-income countries. Completion of this pilot study is necessary to better assess the utility of economic laparoscopic simulators and the impact of simulated surgical exercises on student education.
Table 1. Preliminary Laparoscopic Skill Progression Demographics

<table>
<thead>
<tr>
<th>Demographics</th>
<th>Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sex (M:F)</td>
<td>9:6</td>
</tr>
<tr>
<td>Handedness (R:L)</td>
<td>14:1</td>
</tr>
<tr>
<td>Average sports played</td>
<td>1.86</td>
</tr>
<tr>
<td>Instrument played (Y:N)</td>
<td>10:5</td>
</tr>
<tr>
<td>Played video games &gt; 1 yr (Y:N)</td>
<td>13:2</td>
</tr>
<tr>
<td>Average hours of video games weekly</td>
<td>4.13 hr</td>
</tr>
<tr>
<td>Twirl pens (Y:N)</td>
<td>8:7</td>
</tr>
<tr>
<td>Crossword puzzles (Y:N)</td>
<td>3:12</td>
</tr>
</tbody>
</table>
INTRODUCTION: Our group has shown that personalized video feedback (PVF) is better than a task demonstration video at increasing wound closure skills among surgical interns. However, offering PVF can be time-consuming. We sought to compare the educational effects and time required of grouped video feedback (GVF) vs. PVF.

METHODS: We mailed our matched incoming surgical interns a “Welcome Package” in mid-March for the past three years. The package includes similar resources each year. Trainees were asked to video record themselves performing six tasks (Table 1) three separate times between April 1 and June 15. Following each submission in 2016 and 2017, participants received 2 minutes of personalized feedback on their three separate wound closure videos (PVF). In 2018, incoming interns received 5 minutes of group-based feedback three separate times covering all 6 tasks (GVF). We compared performance (July Surgical Olympics) of these six skills against interns from the previous two years who received PVF on only one skill (suturing).

RESULTS: Twenty-three interns received the pre-residency package and participated in the 2018 Surgical Olympics. This GVF class had a higher overall six station mean score (31.5[SD7.7]) compared to the interns in the 2016 and 2017 PVF classes (25.6[+/+ 8]; p<.0001). Knot tying ability and suturing skill were similar between classes. The GVF group performed better on the remaining four skills (Table 1). Total time of surgical staff and educators spent per class in 2018 (GVF class) was 30 minutes and includes 6 tasks compared to 276 minutes of effort in 2016-2017 classes (PVF includes one skill; Table 2).

CONCLUSIONS: Group-based and personalized video feedback as a component of pre-emptive training had the same effect on improving suturing skills among interns. GVF required less educator editing and voice over time. GVF is effective and efficient in enhancing incoming interns’ performance in multiple skills.
### Table 1. Mean scores for 6 stations for the 2018 vs 2016-2017 July Surgical Olympics scores

<table>
<thead>
<tr>
<th>Tasks</th>
<th>2018</th>
<th>2016-17</th>
<th>p value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reading Chest X-ray (Max 9 pts)</td>
<td>7.4 (0.3)</td>
<td>6 (0.2)</td>
<td>0.003</td>
</tr>
<tr>
<td>Interpreting ABGs (Max 6 pts)</td>
<td>5.2 (0.3)</td>
<td>4.5 (0.2)</td>
<td>0.03</td>
</tr>
<tr>
<td>Open knot tying (30 ties) (seconds)</td>
<td>91 (35)</td>
<td>96 (53)</td>
<td>0.4</td>
</tr>
<tr>
<td>Suturing (Max 10 pts)</td>
<td>7.4 (2.8)</td>
<td>6.6 (2.3)</td>
<td>0.3</td>
</tr>
<tr>
<td>Abdominal anatomy (Max 180 pts)</td>
<td>124 (25)</td>
<td>89 (26)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Fascial closure (Max 20 pts)</td>
<td>14.4 (3)</td>
<td>14.1 (3.6)</td>
<td>0.8</td>
</tr>
</tbody>
</table>

### Table 2. Staff & Educator Time required for editing and voicing over videos in GVF vs PVF groups

<table>
<thead>
<tr>
<th></th>
<th>Length of clip</th>
<th>Reps</th>
<th>Video edit (VE)</th>
<th>Voiceover (V)</th>
<th>Skills included</th>
<th>Effort spent per learner (VE + V)</th>
<th>Effort spent per class (23 interns)</th>
</tr>
</thead>
<tbody>
<tr>
<td>PVF</td>
<td>2 minutes</td>
<td>3 times</td>
<td>2 minutes</td>
<td>2 minutes</td>
<td>1</td>
<td>3*(2+2) =12 minutes</td>
<td>276 minutes</td>
</tr>
<tr>
<td>GVF</td>
<td>5 minutes</td>
<td>3 times</td>
<td>5 minutes</td>
<td>5 minutes</td>
<td>6</td>
<td>3*(5+5) =30 minutes</td>
<td>30 minutes</td>
</tr>
</tbody>
</table>
INTRODUCTION: Robotic surgery is steadily growing as a preferred operative technique due to several advantages. The improved visualization, greater dexterity and integration of intra-operative imaging offer superior surgical capability. This new technology can offer a challenge for surgical training with the operative surgeon removed from the operative field. We offer a proficiency-based step-by-step training program founded on the gastric bypass (GB) operation to acquire skills to perform complex gastrointestinal surgery.

METHODS: Our team consists of a comprehensive, high volume robotic and bariatric surgery program at the largest Navy GME training facility with an ACS-AEI Simulation Center that includes a DaVinci Xi Model Surgical System™ simulator. After a thorough review of the literature, multiple training sessions and case observations, an optimal proficiency based step-by-step training program was determined to learn GB using simulation and patient care training platforms.

RESULTS: The major steps of the GB included: 1) Exploration and Anatomic Landmark identification, 2) Hemi-division of omentum, 3) Creation of Gastric Pouch, 4) Creation of Gastro-jejunostomy and 5) Creation of Jejuno-jejunostomy. Optimal didactic, simulation and patient care training was identified and correlation with required Knowledge, Skills and Abilities (KSA) for military operational readiness was determined.

CONCLUSIONS: Complex gastrointestinal surgery is primarily performed using minimally invasive technique in modern training programs. Military surgeons required annually training in KSAs to maintain military operational readiness. We identified proficiency-based step-by-step program founded on the gastric bypass that provides valuable training to support our deployed operational forces.
Automated Assessment of Surgical Knot Tying

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INTRODUCTION: Knot tying is a fundamental surgical skill often reported deficient by faculty. Existing knot tying models used for resident training allow assessment of tying efficiency and errors but do not address respect for tissue. Development of a model that assesses tissue displacement during knot tying may provide a good surrogate for respect for tissue, allow better detection of expertise, and offer an improved training platform for the acquisition of this skill. The aims of this study were to develop a novel, low-cost, knot tying board (KTB) that provides objective, automated metrics of knot displacement, and to assess displacement while knot tying by level of surgical expertise.

METHODS: The novel KTB was developed in collaboration between engineering students and surgical educators. Joystick potentiometers were incorporated on two parallel rubber tubes to measure vertical and horizontal displacement while tying. Participants used a standardized technique to tie one- and two-handed knots. Differences in time and tubing displacement were compared among junior residents (PGY 1-2), senior residents (PGY 3-5), and attending surgeons; p<0.05 was considered statistically significant.

RESULTS: KTB development required 100 hours and $70.00. The attending surgeons tied two-handed knots faster and with significantly more vertical tubing displacement than residents. Senior residents tied knots significantly faster but with similar tubing displacement as juniors. Similar trends were found for one-handed knots (see Table 1).

CONCLUSIONS: A novel, low-cost KTB was developed which distinguishes among levels of surgical experience. The new performance metric of vertical knot displacement proved more sensitive in detecting performance differences among groups compared with horizontal knot displacement. This board and its novel metrics may promote the development of robust knot tying skill by residents.
Table 1. All data reported as mean ± SE.

| Metric                          | Juniors n=26 | Seniors n=14 | Attendings n=7 | p-value
|--------------------------------|--------------|--------------|----------------|--------
| 2 Handed Knots                 |              |              |                |        |
| Time (seconds)                 | 18.16 ± 1.06 | 11.85 ± 0.69 | 9.78 ± 0.69    | <0.01  |
| Max. Vertical Displacement (cm)| 0.46 ± 0.09  | 0.66 ± 0.12  | 1.08 ± 0.11    | 0.21   |
| Max. Horizontal Displacement (cm)| 0.99 ± 0.05 | 1.03 ± 0.06  | 1.08 ± 0.10    | 0.62   |
| 1 Handed Knots                 |              |              |                |        |
| Time (seconds)                 | 12.12 ± 0.73 | 9.27 ± 0.78  | 7.73 ± 0.76    | **0.01** |
| Max. Vertical Displacement (cm)| 0.54 ± 0.10  | 0.51 ± 0.09  | 0.76 ± 0.14    | 0.80   |
| Max. Horizontal Displacement (cm)| 1.08 ± 0.06 | 1.02 ± 0.06  | 1.06 ± 0.08    | 0.45   |

Notes: Bold indicates statistical significance.
Comparing reverse half-hitch alternating post surgical knots and square knots for closure of enterotomy in a simulated deep body cavity: A Randomized Controlled Trial.

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\textsuperscript{1}Queen's University, School of Medicine, Kingston, Ontario, Canada and \textsuperscript{2}Queen's University, Kingston, Ontario, Canada

\textbf{INTRODUCTION:} Square knots are the standard for hand-tied surgical knots; however, they are difficult to reproduce in a deep body cavity, which can result in slipped knots. We have shown previously that the RHAP knot is easier for new medical learners to learn and achieves knot-tensile strength equivalency to square knots in limited working spaces. This study attempts to demonstrate the non-inferiority of the RHAP knot as compared to the square knot for closure of bowel enterotomies on both flat surfaces and in deep body cavities.

\textbf{METHODS:} We conducted a prospective randomized controlled trial with N=20 novice medical students allocated to either RHAP (n=10, intervention) or square knot (n=10, control) group. Participants were trained to proficiency in knot tying. Participants were then asked to repair a small bowel enterotomy on cadaveric porcine small bowel positioned on a flat surface and in a deep cavity. Integrity of the repair was assessed with a burst pressure.

\textbf{RESULTS:} Time to achieve proficiency in knot tying was equivalent between RHAP and square knot groups (23±3 vs 21±2 min; p=0.91). Time to repair an enterotomy on a flat surface (20±2 vs 19±2 min; p=0.44) and in a deep cavity (17±2 vs 29±7 min; p<0.01) were similar for RHAP and square knot groups. Mean burst pressures for the repair were equivalent for RHAP and square knot groups on a flat surface (101±32 vs 128±39 mmHg; p=0.53); however, were significantly higher for RHAP group in a deep body cavity (105±37 vs 32±13 mmHg; p<0.05).

\textbf{CONCLUSIONS:} Duration of training to achieve proficiency in RHAP and square knots are similar; however, RHAP knots are superior to square knots in simulated deep body cavities for repair of bowel enterotomy. RHAP knots should be taught to surgery trainees as a potential alternative to square knots for use in deep body cavity.
Table 1.

<table>
<thead>
<tr>
<th></th>
<th>RHAP</th>
<th>Square</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Knot Tying</strong></td>
<td><img src="image" alt="Knot Tying Graph" /></td>
<td><img src="image" alt="Knot Tying Graph" /></td>
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<tr>
<td><strong>Flat Surface</strong></td>
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<td><img src="image" alt="Flat Surface Graph" /></td>
</tr>
<tr>
<td><strong>Deep Cavity</strong></td>
<td><img src="image" alt="Deep Cavity Graph" /></td>
<td><img src="image" alt="Deep Cavity Graph" /></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>RHAP</th>
<th>Square</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Burst Pressure</strong></td>
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<tr>
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<td><img src="image" alt="Flat Surface Graph" /></td>
<td><img src="image" alt="Flat Surface Graph" /></td>
</tr>
<tr>
<td><strong>Deep Cavity</strong></td>
<td><img src="image" alt="Deep Cavity Graph" /></td>
<td><img src="image" alt="Deep Cavity Graph" /></td>
</tr>
</tbody>
</table>
INTRODUCTION: Obtaining informed consent (IC) has been identified as a core entrustable professional activity (EPA) for medical students by the Association of the American Medical Colleges (AAMC). However, medical students rarely receive formal instruction before residency, resulting in inconsistent experience and deficiencies in performance. This study seeks to examine medical student perception and understanding of the nature of the current IC process.

METHODS: Based on cognitive interviews, we developed and iterated a 15-item survey aligned with the IC EPA guideline consisting of multiple choice, free text, and 5-point Likert-type (disagree to agree) items. The survey was distributed anonymously to students during their surgery clerkship at one institution. Responses were qualitatively analyzed for frequency of responses and quantitatively analyzed using descriptive statistics.

RESULTS: 24 students responded to the survey (80% RR). 92% reported no prior formal training on the topic of IC. 13% had never observed the IC process. When asked to list elements of an IC, the most frequent responses were risks (79%), benefits (75%), and patient comprehension (50%). Two students (8%) recognized patient autonomy in the decision-making process. Students were inconsistent with medical-legal understanding related to the relative importance of the different elements (Mean=3.6, SD=1.5), differences based on environment (Mean=3.2, SD=1.6), and who can legally obtain consent, specifically regarding students (Mean=2.4, SD=1.4) and advanced practice providers (Mean=4.6, SD=1.0). Students answered “neutral” on their abilities to perform an adequate consent (Mean=3, SD=1.0).

CONCLUSIONS: This preliminary data suggest inconsistent exposure and experience of medical students to and with the informed consent process. Although the majority of students demonstrate some understanding of the fundamental principles, there is a distressingly high proportion of whom who lacked basic understanding. As we collect more data, we will develop a tailored EPA-aligned IC curriculum for medical students.
PAPERS SESSION II
SATURDAY, MARCH 16, 2019
Surgical Games: A Simulation-Based Structured Assessment of Orthopaedic Surgery Resident Technical Skill

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Hospital for Special Surgery, New York, New York

INTRODUCTION: Simulation-based education and objective evaluation of surgical skill have been incorporated into many surgical training programs. Here we describe the development and implementation of a timed, multi-task, station-based Surgical Games using direct observation to evaluate orthopaedic resident surgical skills.

METHODS: Participants in the study were post-graduate-year (PGY) 2-5 orthopaedic surgery residents from a single academic institution. Residents completed four timed, observed, and simulated surgical tasks: (1) cadaveric carpal tunnel release (CTR), (2) saw-bones model of total knee arthroplasty (TKA), (3) saw bones ankle fracture open reduction internal fixation (ORIF), and (4) knee arthroscopy simulator (KAS) of removal of loose body. Performance grading was performed using standardized score sheets by attending surgeons. Residents were compared by PGY and amount of prior task-related training during residency. One-way analysis of variance was used to compare performance on each station per year of training. Spearman correlation coefficients were calculated to determine relationships between prior task-specific training experience and overall performance at each station.

RESULTS: A total of 32 residents (18% female and 81% male) were assessed at the four stations. Total scores were significantly different for CTR (p =0.006), TKA (p=0.05), and the KAS (p = 0.004) by year of training, but not for the ankle ORIF task. Residents with more task-specific experience performed significantly better on the KAS (p<0.001), TKA (p = 0.002), and CTR (p=0.02) tasks but not on the ankle ORIF task (p=0.1). Overall, residents rated the exercise valuable to their education with mean scores of 3.9 ± 0.54 on a 5-point Likert Scale.

CONCLUSIONS: This Surgical Games exercise provided an objective evaluation of surgical skill that was correlated to year in training and prior experience in skill-specific rotations for the KAS, TKA, and CTR tasks. This surgical skills assessment provided an opportunity for effective structured feedback and identification of areas for improvement.
The Use of Virtual Humans to Assess Surgeon Communication Skills in a Simulated Laparotomy

Josue W. Menard, MD1, Adeline Deladisma, MD1, Daniel Escobar, MD1, Ruchir Puri, MD1, Steve Yule2, Roger Diaz2, Lampotang Sem3, Ben Lok3 and Charlotte O. Bedsole, DNP, RN, CNOR1

1University of Florida, Jacksonville, Jacksonville, Florida, 2 Neil and Elise Wallace STRATUS Center for Medical Simulation, Boston, Massachusetts and 3University of Florida, Gainesville, Gainesville, Florida

INTRODUCTION: We have previously validated a checklist for performing a laparotomy in a simulated model. In this study, we have integrated virtual humans (VHs) into this simulated laparotomy scenario to assess surgeon response to VH communication challenges.

METHODS: All of the simulated interactions were conducted in an operating room in the outpatient surgical center (OSC) at the University of Florida – Jacksonville. Three interactive VH teammates (anesthesiologist, circulating nurse and surgical technologist) were projected on a 40-inch monitor mounted on a rolling stand and connected to a Dell computer. Nineteen surgeons (6 faculty and 13 residents) were videotaped interacting with VHs while performing a surgical time out and laparotomy on a simulated model (Figure 1). Communication challenges consisted of participants leading a surgical timeout, 2) addressing a timeout interruption (VH anesthesiologist receives phone call) and 3) managing an incorrect sponge count. Expert raters (N=5) assessed videotaped performance using a binary communication and previously validated simulated laparotomy checklist.

RESULTS: Nine faculty and 13 residents (4 senior residents = PGY3-5, 9 junior residents = PGY1-2) completed the simulation. All participants felt the activity was valuable and believable (i.e. face validity). All but two participants initiated a surgical timeout, however, 3 residents failed to address the timeout interruption. While all faculty addressed the timeout interruption, the majority failed to restart the timeout. With respect to managing the incorrect sponge count, all faculty stopped operating and searched the abdomen while almost 50% of faculty and residents did not ask for a recount and a radiograph of the abdomen.

CONCLUSIONS: We have successfully integrated VHs with a simulated laparotomy model to teach/assess communication/teamwork and psychomotor skills. Participant performance demonstrates a need for deliberate practice with feedback in correctly performing a surgical time out and a laparotomy with an incorrect sponge count for surgical residents and faculty.
Figure 1. Surgeon Performs Simulated Laparotomy with VH Operating Room Personnel.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Resident (%)</th>
<th>Faculty (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Conducted Time Out</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Prompted</td>
<td>1 (8.3)</td>
<td>1 (16.7)</td>
</tr>
<tr>
<td>Initiated</td>
<td>11 (91.7)</td>
<td>5 (83.3)</td>
</tr>
<tr>
<td><strong>Addressed Interruption</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>No</td>
<td>3 (30.0)</td>
<td>0 (0)</td>
</tr>
<tr>
<td>Yes, Resumed Time Out</td>
<td>2 (12.5)</td>
<td>4 (66.7)</td>
</tr>
<tr>
<td>Yes, Restarted Time Out</td>
<td>5 (50.0)</td>
<td>2 (33.3)</td>
</tr>
<tr>
<td><strong>Response to Incorrect Count</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Stopped Operating</td>
<td>7 (63.6)</td>
<td>5 (100)</td>
</tr>
<tr>
<td>Asked for Recount</td>
<td>7 (63.6)</td>
<td>3 (60.0)</td>
</tr>
<tr>
<td>Asked for X-Ray</td>
<td>6 (54.5)</td>
<td>2 (40.0)</td>
</tr>
<tr>
<td>Searched Abdomen</td>
<td>10 (90.9)</td>
<td>5 (100)</td>
</tr>
</tbody>
</table>
Simulation Training for Endoscopic Management of Upper Gastrointestinal Bleeding: A Nationwide Survey of Rural Surgeons’ Needs and Preferences Analysis

Shawn M. Purnell, MD¹,², Daniel J. Vargo, MD², Michael D. Sarap, MD, FACS³, John J. Nguyen-Lee, MD⁴ and Brian J. Dunkin, MD, FACS⁴

¹Houston Methodist Hospital, Department of Surgery, Houston, Texas, ²University of Utah, Department of Surgery, Division of General Surgery, Salt Lake City, Utah, ³Southeastern Ohio Regional Medical Center, Cambridge, Ohio and ⁴MITIE, Houston, Texas

INTRODUCTION: Published needs analyses of rural surgeons have identified interest in training for the endoscopic management of upper gastrointestinal bleeding (UGIB). While simulation models currently exist for training in the management of UGIB, their cost and complexity are prohibitive in the rural setting. This study aims to identify the needs and preferences of practicing rural surgeons for an endoscopic simulation model of UGIB.

METHODS: Rural surgeons were contacted via the American College of Surgery Advisory Council for Rural Surgery email list server and discussion board with an electronic link to the REDCap survey. Descriptive statistics and cross-tabulations were calculated using Stata/MP.

RESULTS: A total of 66 responses were received over six weeks, representing all four US regional divisions. Seventy seven percent (51/66) of respondents perform >100 endoscopy cases per year. A majority have no experience with simulation models (77%), citing cost, time, and access to training courses as the three most prohibitive factors. Thirty three percent (17/66) lacked confidence in managing UGIBs and 73% were “interested” or “very interested” in receiving additional training. Preference analysis revealed that respondents preferred a portable simulation model (81%) that costs between $500-$1000 (46%), and requires 1-2 weeks of training (34%). Being able to train independently was “important” to “very important” (60%), and verbal feedback from an expert was viewed as the most helpful type of feedback (61%). Years in practice was not correlated with comfort in managing UGIB or interest in additional training (p=.74 and p=.44 respectively), but case volume was (p=.02).

CONCLUSIONS: Rural surgeons frequently perform flexible endoscopy in their practice and are interested in further training for the endoscopic management of UGIB. These results will be used to develop a simulation platform for training in the endoscopic management of UGIB that meets rural surgeons’ needs.
INTRODUCTION: How well surgeons tie ligatures to occlude vessels is paramount. Practicing knot-tying without gloves or without exposure to substances like blood or fat may reduce knot-tying proficiency. We investigated whether there was a difference in the open knot-tying proficiency when residents were bare-handed, wearing gloves, or with gloves coated in butter.

METHODS: Twenty-one surgical interns were told to perform their best with three knot-tying tasks on simulated vessels (balloons): two-handed knots and both right and left one-handed knots. Each task was performed under three conditions: bare-handed, wearing gloves, and with butter-coated gloves. The quality of each knot was assessed based on leakage, accuracy, and time. Participants completed a questionnaire regarding their thought process while performing the tasks.

RESULTS: A total of 567 knots (189/condition) were assessed. While the mean time spent per knot (3 throws each) was 16, 17, and 17 seconds for bare, gloved, and gloves with butter, respectively (p=NS), intern accuracy of knots (tied exactly on the marked line) was mediocre: 57%, 65%, and 61% for each condition, respectively (p=NS). Worse yet, mean leak rates were 72%, for all three conditions (p=NS). The questionnaire revealed that 50% of interns put their main focus on time, 33.3% on leakage, and 16.7% on accuracy. Most (64%) considered using butter-coated gloves was most realistic to their operating room experience and most (71%) preferred to practice with butter-coated gloves.

CONCLUSIONS: Although we hoped to differentiate an efficient and cost-effective method to help interns learn to tie quick, accurate, and secure knots in a lifelike environment, this study identified two crucial efforts ahead for our education team and surgical interns: prioritize mental focus on tying secure knots and practicing to proficiency to avoid leakage. Speed and accuracy are irrelevant if knots leak.
Use of Sensors to Quantify Procedural Idle Time: Validity Evidence for a New Mastery Metric

Kenneth H. Perrone, MD¹, Hossein Mohamadipanah, PhD¹, Su Yang, BS¹, Brett Wise, BS¹, Anna Witt, BS¹, Cassidi Goll, BS¹, Stefani Dawn, PhD², Wade Eichhorn, BS² and Carla M. Pugh, MD, PhD, FACS¹

¹Stanford University, Stanford, California and ²7-Sigma, Minneapolis, Minnesota

INTRODUCTION: Quantification of mastery is the first step in using objective metrics for teaching. We hypothesized that top performers have characteristic motion metrics including less time spent idle during intubation than lower tier performers.

METHODS: At the 2018 Anesthesiology Annual Meeting, 86 participants intubated a normal airway (NA) and a burnt airway (BA) simulator. Intubation order was randomized. Top performers were defined as participants who successfully intubated both simulators and accomplished each task in less than the median successful intubation time for each simulator. Participant’s hand movements were quantified using electromagnetic sensors placed under latex-free gloves. Idle Time was defined as the duration of time when both hands were not moving. Non-parametric statistical comparisons were used to compare TPs with LTPs during their first intubation.

RESULTS: Top performers showed significantly less (p=0.01) Idle Time (median 0.86±1.76) when intubating the NA compared to lower tier performers (median 6.14±9.12). Likewise, top performers showed significantly less (p<0.01) Idle Time (median 2.80±4.20) when intubating the BA compared to lower tier performers (median 17.79±12.47), (Figure 1). When intubating the NA compared to the BA, there was no difference for both top performers (median 0.86±1.76 vs 2.80±4.20 p=0.69) and lower tier performers (median 6.14±9.1 vs 17.79±12.47 p=0.08).

CONCLUSIONS: Similar to our previous findings with other procedures, Idle Time was shown to have known groups validity evidence when comparing top performers with lower tier performers. Further, Idle Time was correlated with procedure difficulty in our prior work. However, we did not observe a significant difference despite the 2-3 fold increase in mean Idle Times for both groups comparing the NA to the BA. Our findings support the continued exploration of Idle Time as an important indicator of mastery.
Table 1.

<table>
<thead>
<tr>
<th>Normal Airway</th>
<th>Burnt Airway</th>
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![Images of Normal and Burnt Airway](image)

Figure 1: Top performers had less Idle Time than lower tier performers who were defined as participants who did not successfully intubate both simulators or who took longer than the median time to successfully intubate at least one simulator.
Using Causal Models in Psychomotor Performance Assessment

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University of Minnesota Medical School, Minneapolis, Minnesota

INTRODUCTION: The push toward competency based medical education has increased administrative pressure on medical faculty and education staff. Expert evaluators for procedural task competency are scarce because of the strenuous clinical and administrative workloads. Because of this, we developed a causal model which encodes expert definitions of procedural tasks for automatically assessing psychomotor performance data from high fidelity task simulations. This allows learners to independently complete the tasks, receive feedback, and be objectively compared to expert performance.

METHODS: Fifteen learners completed a standardized high-fidelity simulation task under audiovisual recording, which were reviewed and compiled into psychomotor event sequences by two raters. Learner data is fed to the causal model, which reports on how well data clusters round a set of expert-identified “ideal” points (time, label pairs). The audiovisual recordings, event sequences, and this report are then made available to expert faculty reviewers.

RESULTS: Using labeled time series data representing the sequence of a learner’s psychomotor actions, the distance of a given action from an “ideal” point can be computed. Of 57 events matching the ideal point’s label, 47 occurred within one (1) standard deviation (SD), 5 within two (2), and 5 outside the accepted range of 2 SDs. Because the model is able to report the learner each data point belongs to, we are able to direct faculty toward learners more likely to be in need of help.

CONCLUSIONS: The causal model suggests how well learners performed specific events in a complex procedural task. This assisted faculty with identifying outliers likely in need of attention. Faculty appreciated the availability of audiovisual recordings, not having to attend each simulation, and found the summarized report helpful for targeting learner feedback. They felt the causal model gave a “better idea” of the quality of an individual’s performance because it better encoded clinical performance benchmarks.
POSTER ROUNDS GROUP A
SATURDAY, MARCH 16, 2019
Resident Opinions of the Value and Optimal Content of a Technical Skills Curriculum using Simulation

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Cleveland Clinic, Cleveland, Ohio

INTRODUCTION: Simulation training in general surgery residency can help enhance surgical skills. We recently underwent a major revision to our skills curriculum. We aim to explore the opinions on simulation training in general surgery at our institution to optimize the utilization of these resources.

METHODS: We administered an anonymous survey to our general surgery residents.

RESULTS: Response rate was 20 out of 70 residents (29%). 9 (47%) junior and 10 (53%) senior residents participated in the study. 95% of residents felt that mandatory time should be set aside for simulation training. The majority of residents did not feel that proficiency must be demonstrated prior to performing them on a patient (68% felt this was not necessary for open skills, 58% laparoscopic skills, and 63% endoscopic skills). Of those who felt demonstration of proficiency was necessary prior to patient contact, hand-sewn small bowel anastomosis, vascular anastomosis, tracheostomy/cricothyroidotomy, and intracorporeal laparoscopic suturing were most important (88% each). All residents felt that inanimate models were inferior to live animal (67%) or cadaveric (37%) models. The majority (53%) of residents spend at least 2 hours per week on their own in the simulation lab outside of dedicated simulation time, mostly during works hours (77%). 32% report not utilizing the simulation lab outside of dedicated time. 83% of these cite a lack of time. If given protected time, 83% would take advantage, mainly to enhance their skills in a particular area (60%). The majority (78%) of our residents feel that our simulation curriculum is beneficial. Our findings are consistent with prior research.

CONCLUSIONS: Residents believe the optimal technical skills curriculum using simulation should comprise of cadaveric and live animal models directed at specific general surgery skills. Protected time will enhance resident independent practice outside of the required curriculum.
INTRODUCTION: General Surgery training covers a broad spectrum of pathologies and procedures and each surgery program has different proportions of training in different areas of general surgery. There is a requirement for general surgery programs to train residents in the management of thermal burns. Some programs struggle to provide their residents enough clinical exposure to burn patient management. There is a need for new educational solutions to fill this gap. Previous studies have demonstrated the effectiveness of simulation-based education in general surgery training. We hypothesize that using simulation to teach burn management may be an effective tool for general surgery residents. To assess the effectiveness of this training, we will use a structured mock oral board session with each resident pre-and post-training.

METHODS: Our study includes general surgery residents from PGY 1 to 5 (N=22) as participants. We are using a mock oral board as an assessment tool in the pretest to determine the baseline knowledge of the participants. After pretest, the participants are randomly divided into two groups. Group one attends a lecture based session delivered by a trauma surgeon and group two participates in a hybrid simulation session followed by a debriefing session. After completion of the training, both the groups will be assessed by a mock oral board posttest to compare improvement in the core competencies such as patient care, medical knowledge, professionalism, practice-based learning improvement, and systems-based practice.

RESULTS: Pending.

CONCLUSIONS: We feel that using mock oral board examinations as an assessment tool in simulation based sessions may provide us a better in-depth understanding of improvement in residents’ performance and will help us to identify if simulation-based training is more effective than traditional teaching methods for low frequency/high risk events.
INTRODUCTION: General Surgery trainees are expected to interpret cross-sectional imaging studies. Education often occurs without any formal training on the subject. The benefit of 3-Dimensional (3D) anatomical models for radiology education has not been completely clarified. The aim of this study is to evaluate the impact of radiological anatomy lectures and the benefit of incorporating 3D models.

METHODS: A randomized controlled crossover trial of 28 surgery interns was conducted. The participants were given an image-based radiological anatomy baseline test and later randomized into two groups (A and B). Both groups were exposed to a series of six 40-minute teaching sessions on focused radiological anatomy. Each session consisted of pre and post-quizzes (immediate tests), a 20-minute lecture, and 10-minute exposure to either 3D anatomical models or surgical-skills tasks. During the first three sessions, Group A (n=14) and Group B (n=14) were exposed to 3D models and surgical-skills tasks, respectively; the groups crossed-over for the last three sessions. A post-test was administered 1 week after the last session.

RESULTS: Baseline radiological anatomy knowledge was similar between Group A and B (Mean A=24.4±9.1; Mean B=26.0±10.6, p=0.71), both groups improved their Post-test scores (Mean=32.5±6.9, p<0.001 and 33.15±8.8, p=0.007, respectively). Participants exposed to 3D models and participants performing surgical-skills tasks obtained similar scores in their pre (Mean=2.6±1.6 and 2.7±1.5, p=0.736, respectively) and post-quizzes (Mean=4.0±1.1 and 4.1±1.1, p=0.894, respectively). These two groups had a positive overall immediate improvement (Mean=1.4±1.4, p<0.001 and 1.3±1.6, p<0.001, respectively); however, this improvement was not different between the two groups (p=0.672).

CONCLUSIONS: The implementation of focused and interactive 20 minute lectures is an effective method to enhance PGY-1 residents’ overall radiological scoring with immediate tests. While integrating 3D anatomical models to assist with comprehension of cross-sectional images had no additional benefit, long term retention must be assessed in 6 months for more complete analysis.
Laparoscopic Port Placement Concepts; It’s All About Fundamentals

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INTRODUCTION: Laparoscopic surgeries depend on optimal port location. The concepts of triangulation, distance to the target organ and specific anatomy, require mastery to obtain optimal port-placement locations. Many trainees memorize port placement locations for laparoscopic surgeries, but when tasked with unique procedures or anatomical variants, the concepts of port placement become essential. Evaluation of the understanding and application of these concepts has not been described in the literature.

METHODS: Utilizing low-fidelity models of the abdomen with predefined port-entry sites, participants were given an assessment that consisted of four simulated scenarios. An instructional video with fundamental port-placement concepts was distributed after the baseline assessment to all the participants and the same test was given 6 months later. After completing four scenarios, trainees were given 90 seconds to complete a five question quiz. Our primary outcome included total score and its improvement between the baseline and post-intervention assessments. Secondary outcomes were correct performance on routine tasks (positioning & palpation of anatomical landmarks), port-location, and quiz score.

RESULTS: A total of 63 PGY-1 to 5 surgical trainees completed the pre & post-intervention assessments. Participants were split into juniors (PGY 1-2, n=38) and seniors (PGY 3-5, n=25). 63% of the junior residents and 60% of the senior residents watched the instructional video in the interim. Junior residents who did watch the interventional video showed significant improvement in the total score (Mdn=10.25, p<0.01), as well as in the routine tasks (Mdn=4, p<0.01), port-location (Mdn=4, p<0.01), and quiz score (Mdn=1.8, p<0.01). Significant differences between the junior and senior residents were observed in the total score (Mdn=17.6 and 27.8, p<0.01), routine tasks (Mdn=8.2 and 12.5, p<0.01), port-location (Mdn=6.6 and 10.4, p<0.01), and quiz scores (Mdn=3 and 5.5, p<0.01).

CONCLUSIONS: An instructional video for learners pertaining to the concepts of port-placement is an effective way to educate and improve assessment scores.
Does Variability Among Surgical Skills Diminish Throughout Residency Training? Analysis of a 5-Task Surgical Simulation Curriculum Starting Day 1

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INTRODUCTION: Simulation curriculums are not yet standardized amongst surgical programs, and are typically implemented later in residency. Our aim was to institute a 5-task curriculum to assess surgical technical skills longitudinally during internship.

METHODS: First-year residents completed five simulation tasks—suturing, knot tying, vascular anastomosis, Fundamentals of Laparoscopic Skills (FLS) peg transfer and FLS intracorporeal suturing. Assessments occurred just before residency, mid-year, and at the end of the academic year. Graders were blinded to subject identity. Task performance improvement was analyzed using repeated measures ANOVA, Cochran’s Q test and Friedman test. Univariable analysis was used to assess association between participant factors and overall performance.

RESULTS: 19 residents—8 (42%) categorical, 4 (21%) urology, 3 (16%) interventional radiology, 2 (11%) plastics, and 2 (11%) non-designated preliminary (NDP) interns participated in this study. In the FLS-peg transfer task, mean time to completion improved over the year with a decreased variability between sessions (145.4 (+49.7), 111.1 (+ 47.4), and 95.3 (+ 28.3) seconds respectively). Total task scores, specifically FLS-peg transfer and knot tying, trended towards improvement with each session, although not statistically significant (Figure 1). Intern characteristics impacted total knot tying task score in the initial session. NDP interns had starting scores in the 25th percentile, and were 2.6% as likely as their categorical counterparts to have an increase (p<0.05) in their total score. However, by the second session, NDP intern scores were >75th percentile with no association between intern type and total score. Interns were exposed to the same surgical training, with 47.4% completing at least two of the three core surgical rotations by mid-year.

CONCLUSIONS: Technical skills of beginning surgical residents were assessed longitudinally with the institution of a 5-task curriculum. Periodic assessments showed improvement in each major task. Additionally, as residents were exposed to the same surgical training, the skill score variability decreased.
Training Multidisciplinary Teams in Nontechnical Skills and OR Safety Using Simulation Based Training

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University of Rochester Medical Center, Rochester, New York

INTRODUCTION: Teamwork and communication are invaluable to patient safety and optimization of crisis control in the operating room (OR). While the surgical safety checklist (SSC) has been shown to reduce mortality, its full penetrance into perioperative practice is incomplete at our institution. We created a simulation model to develop and refine nontechnical skills integral to maintaining patient safety in the OR. We hypothesized that OR team simulation training would enhance SSC adherence and general perioperative safety attitudes.

METHODS: Complete OR teams (anesthesia, nursing, and surgery) participated in a high-fidelity simulation program modeling an intraoperative crisis (intra-abdominal hemorrhage). Incongruences and unexpected events were included to highlight potential pitfalls and demonstrate importance of teamwork and utilization of the SSC. Investigators moderated debriefing sessions at the end of each stage and at case conclusion. Pre and post simulation surveys were administered.

RESULTS: 84 staff members completed the pre-simulation survey. 80 completed the post-simulation questionnaire. The percentage of participants that viewed the surgical sign out (in the SSC) as important for patient safety increased from 60 to 80% after training. Post simulation, participants reported that many focuses of the scenario such as paying attention to the pauses, involving all team members, employing closed loop communication and fostering an empowering environment are all potential areas of improvement in real OR settings. Before the session, less than half of surveyed individuals believed simulation to be an effective way to teach OR teamwork, which increased to 84% afterward. On post simulation survey, 100% of participants agreed that their OR team would benefit from simulation and team training.

CONCLUSIONS: Simulation can be used to strengthen interprofessional teamwork, enhance attitudes toward SSC utilization, and promote awareness of potential communication breakdowns that may jeopardize patient safety.
Reconstruction of Marginal Mandibular Defects Utilizing Bone Marrow Aspirate Concentrate from the Anterior Iliac Crest: A Less Morbid Osteogenic Option

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Thomas Jefferson University Hospital, Philadelphia, Pennsylvania

**INTRODUCTION:** Bone marrow aspirate concentrate (BMAC) as an option for reconstruction of marginal mandibular defects is not described eloquently in the maxillofacial literature. The aim of this paper, is to describe our surgical technique using BMAC, allograft, platelet rich plasma (PRP) and bone morphogenic protein (rhBMP-2). We have compared our approach with the traditional iliac crest harvest technique for reconstructing marginal mandibular defects.

**METHODS:** 10 patients included in the retrospective case series were treated between 2014 and 2017 by 3 surgeons. Mean age was 44 years (range from 19 to 77 years). Bone marrow aspirate was obtained from the anterior iliac crest. In this case series we utilized the anterior approach. When appropriate, a custom milled mandibular reconstruction plate was placed. The pathology included KOT, Ameloblastoma, CGCG, Cavenous Hemangioma, Dentigerous Cyst. Preoperatively, a maxillofacial CT scan and plain films of the hip were obtained.

**RESULTS:** The success of our surgical technique was the ability to regenerate lost mandibular osseous contour for functional rehabilitation and to lower patient morbidity. There were no postoperative complications. Based on these parameters, we report 100% success. With this technique, we noted a reduction in the operating time by 67% and a shorter hospital stay (by at least 13 hours) when compared to the traditional technique of harvesting the anterior iliac crest. The postoperative pain was controlled with an oral analgesic regimen, thus eliminating the need for a local anesthetic infusion pain pump employed when traditional harvesting techniques were used.

**CONCLUSIONS:** Our surgical protocol of combining BMAC, allograft, PRP, and BMP is a less morbid osteogenic option when compared to traditional methods of harvesting bone from the anterior iliac crest for reconstructing marginal mandibular defects. Reduced operating times, lowered post operative pain and a shorter hospital stay were noted which resulted in an overall reduction in surgical costs.
Residency preparatory courses effectively prepare graduating medical students for surgical internship

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Indiana University School of Medicine, Indianapolis, Indiana

INTRODUCTION: Medical schools frequently offer residency preparatory courses (“prep courses”) aiming to better prepare senior medical students for surgical internship. Our goal was to determine the effect of prep courses on resident readiness at the beginning of intern year using the scenario-based American College of Surgeons’ Entering Resident Readiness Assessment (ACS-ERRA) and the high-fidelity standardized patient ACS Objective Structured Clinical Exam (ACS-OSCE).

METHODS: All entering surgery residents (n=24) at our institution in 2018 were surveyed about residency prep course participation during medical school and had their baseline clinical decision-making skill assessed using the ACS-ERRA during their first week on service. After a departmental orientation, two months of weekly didactics, intense skills training in our comprehensive surgical simulation center, and clinical service, residents’ clinical decision-making was reassessed using five ACS-OSCE scenarios. Performance differences between residents that had completed a prep course and those that had not were compared on both assessments using Welch’s two-sample t-test. A linear regression was conducted to determine predictors of resident performance on the ACS-ERRA and ACS-OSCE using United States Medical Licensing Exam (USMLE) scores and prep course participation as independent variables.

RESULTS: Residents who had participated in a prep course (n=15) performed significantly better on the ACS-ERRA than those who had not (n=9; t(11.9)=2.2, p=0.049). Further, prep course participation was a significant predictor of performance for the ACS-ERRA (B=0.05, p=0.022, adjusted R-squared=0.18) while USMLE scores were not (p=0.058). No significant performance differences were observed on the ACS-OSCE between groups and no baseline variable predicted ACS-OSCE performance.

CONCLUSIONS: Interns who participated in a residency preparatory course during medical school performed better on the ACS-ERRA than those who did not, demonstrating the benefit of prep courses for new surgical interns. No differences were observed on the ACS-OSCE, which may reflect significant learning that takes place at the beginning of intern year.
POSTER ROUNDS GROUP B
SATURDAY, MARCH 16, 2019
Multiuse low-cost hematemesis mannequin

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VA Pittsburgh Healthcare System, Pittsburgh, Pennsylvania

INTRODUCTION: Among patients with cirrhosis, one-third of patients with varices will develop variceal hemorrhage. Current management involves early resuscitation, including airway support if required. Guidelines recommend the use of balloon tamponade tubes in massive hemorrhage as a bridge until the patient can receive advanced treatment. Any delay in treatment can have devastating results in patient outcomes. To avoid any delay in response healthcare professionals, need to know their responsibilities when responding to this medical emergency. Interdisciplinary team training provides the opportunity for each member of the team to practice responding to this emergency event in a safe, learning environment. To create the appropriate level of fidelity, a full body mannequin that can be intubated, have a balloon tamponade tube inserted/inflated and actively bleeding from an esophageal varicosity is desired. After an extensive search, no full body mannequin was found that possessed the desired capabilities.

METHODS: To address the need for a specialized full body mannequin a multidisciplinary planning team consisting of a simulation fellow, dentists, and a biomedical engineer was formed. Multiple mannequins were evaluated based upon the three identified criteria of intubation, tube insertion/inflation, and active bleeding. All mannequins could be intubated but would not support the insertion of a balloon tamponade tube. Both low and high-fidelity mannequins, as well as difficult airway trainers, were evaluated. None of the mannequins assessed could tolerate balloon tamponade insertion. High fidelity mannequins possess internal circuitry which prevented them from tube insertion and the housing any fluid used during inflation. The decision was made to re-purpose and create adaptions to an old model mannequin, to create a full body mannequin capable of meeting our three criteria.

RESULTS: N/A

CONCLUSIONS: Variceal hemorrhage requires a rapid response by healthcare providers. To address this simulation scenario, optimal fidelity is needed.
International Collaboration through Simulation in the Health Sciences

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¹University of Minnesota, Minneapolis, Minnesota, ²BMCRI- Bangalore Medical College and Research Institute, Bangalore, India and ³St John's Medical College, Bangalore, India

INTRODUCTION: Simulation-based education is becoming more common in health sciences training both within and beyond the United States. As an educational methodology with technology and practices capable of standardization, simulation is uniquely suited to enable international collaboration, including educational research and shared curricula. With this in mind, an interdisciplinary team from the University of Minnesota’s One Health Simulation Program (UM) collaborated with the faculty from the Bangalore Medical College Research Institute (BMCRI) to develop and support a new simulation center in Bangalore, India. An initial workshop was held to share simulation best practices, provide examples of simulation-based training and research, and develop an international partnership.

METHODS: A four-day workshop, held onsite in Bangalore, India, consisted of keynote presentations, round table discussions, skills training, and immersive scenarios. At the workshop’s conclusion, BMCRI faculty co-led simulation training scenarios with the UM team. Evaluations were completed following simulation experiences by all participants including medical students, residents, nurses, allied health providers, and faculty. Respondents used a 6-point agreement scale (from 1=Disagree Strongly to 6=Agree Strongly) to assess twelve different items related to their workshop experiences, ranging from: “preparation for simulation” to “overall value of the simulation.” Participants were also provided the opportunity to write comments regarding their experience.

RESULTS: There was strong agreement regarding the overall value of the simulation experiences. All quantitative responses (n=178) averaged between 4.9 and 5.5 (4=Slightly Agree, 5=Agree, 6=Strongly Agree). Similar responses were seen across participant type and simulation scenario. The most important themes emerging from the open-ended questions related to “The opportunity to practice effective team communication” and “The opportunity to gain confidence and improve patient care skills.”

CONCLUSIONS: Workshop data demonstrate the enthusiasm and overwhelming support from participants to advance the new center and simulation-based training at BMCRI. We look forward to partnering in educational research and promoting interprofessional training.
Table 1.

**Workshop Components**

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<tr>
<th>Presentations</th>
<th>Scenarios</th>
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<tr>
<td>Essentials of Simulation for</td>
<td>Anaphylaxis</td>
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<td>Effective Teaching, Learning,</td>
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<td>and Assessment</td>
<td>Trauma</td>
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<tr>
<td>Using Simulation to Teach</td>
<td>Insecticide overdose</td>
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<td>Interprofessional Teamwork</td>
<td>Snake bite</td>
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<td>Simulation Design Strategies and</td>
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<td>Equipment Planning</td>
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<tr>
<th>Skills</th>
<th>Round table Discussions</th>
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<td>Airway management</td>
<td>Scripted debriefing skills</td>
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<tr>
<td>Vascular access</td>
<td>Scenario development</td>
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<tr>
<td>Advanced cardiac support</td>
<td>Simulation operations</td>
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<td>Developing performance checklists</td>
<td>Competency assessment</td>
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Introducing Tattoos to Advanced Trauma Life Support (ATLS): A Process Improvement Initiative

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¹USF Health CAMLS, Tampa, Florida and ²University of South Florida, Tampa, Florida

INTRODUCTION: The Advanced Trauma Life Support® (ATLS®) Course is a continuing medical education activity that provides physicians with a standard approach to trauma care. Participants are required to successfully pass both a cognitive exam and skills assessment to earn an ATLS® certification. The skills assessment involves a supervised evaluation of a learner’s primary and secondary trauma survey on a standardized patient (SP). Our center implemented use of new moulage tattoos in place of standard moulage application. We assessed feedback data regarding the use of moulage tattoos as a process improvement initiative.

METHODS: To better understand the differences between the new and standard techniques, we compared data from two 2-Day 9th edition ATLS courses. The two courses were structured in the exact same manner except for the new moulage technique. The standard moulage course was completed in July 2018; the new method was completed in September 2018. Data gathered for our PI initiative included: cost of moulage, total time for moulage preparation, SP time for preparation, staff time to place moulage, and opinion surveys. Surveys were distributed to SPs, staff applying moulage, the ATLS coordinator, and ATLS instructors.

RESULTS: Total cost savings for ATLS Tattoo Moulage was $610.95 (62% savings)SP preparation time reduced by 150 minutes Staff preparation time was reduced by 120 minutesSP, Staff, ATLS coordinator, and ATLS instructors extremely favorable responseNo moulage required reapplication or adjustment during the skills assessment portion of ATLS testing

CONCLUSIONS: Cost containment and resource utilization play a significant part in process improvement. This preliminary study describes a new method of moulage application that standardizes the appearance and reduces time and effort in SP preparation, thus increasing consistency and reducing total cost. Future multisite studies should be undertaken to replicate these results and investigate any impact on student performance metrics.
A prospective, Randomised, Controlled Trial assessing the rate of decay of virtual reality colonoscopy (psychomotor) skill

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**INTRODUCTION:** Colonoscopy is a complex psychomotor task, that requires the amalgamation of motor and sensory skill sets, as well as the use of higher cortical functions. These functions involve attention control, behavioural organisation, gross and fine motor movement. These unique demands are comparable to surgical skills a surgeon may need to develop or demonstrate at various stages of their career. Furthermore, once the requisite skills have been acquired, it is not clear how long these skills remain optimal.

**METHODS:** 30 colonoscopy naïve medical students were randomly assigned to a control condition that tested the day after the successful completion of training; a 2 weeks group that tested 2 weeks after the completion of training or to a 1 month group that tested 1 month following the completion of training. All subjects were asked to perform an abstract task aimed at developing the core skills needed to perform a colonoscopy. The participants were trained to competency and were then tested after the duration of time dependent on their group allocation, where they were required to achieve competency again.

**RESULTS:** The results showed a significant difference among the three groups (F\textsubscript{2,26}=15.08, P=0.0001). Subjects testing after 2 weeks took more attempts to reach competency than participants tested the next day with the difference trending towards significance (t=1.85, P=0.075). Subjects testing after a month took significantly more attempts than those tested the following day (t=5.42, P=0.0001) as well as those tested after 2 weeks (t=3.42, P=0.002). The relationship of these differences was analysed and determined to be linear (difference in mean =2.49, 95% CI =1.55 – 3.43, P =0.0001)

**CONCLUSIONS:** Colonoscopy skills significantly decay sometime after 1 week and all the way to 1 month, with the rate of decline being proportional to the period of non-use. Speed tasks are more resistant to decay than accuracy tasks
A Laboratory Model for Ureteroneocystotomy

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¹Retired and ²University of Wisconsin, Madison, Wisconsin

INTRODUCTION: Multiple new approaches to managing vesicoureteral reflux has resulted in a significant decline in open ureteroneocystotomy. An ability to perform this key urologic procedure is critical for practicing urologists. In many urologic training programs there are an insufficient number of cases available to master the multiple methods of open ureteroneocystomy. We developed a hands-on high fidelity low cost laboratory practicum to facilitate the development of Urologic residents’ surgical skills in the performance of the most common open ureteral reimplantation operations.

METHODS: Porcine bladders with intact ureters/bladders were used as models for various ureteroneocystomy reimplant techniques. Videos of the operative procedures were created and posted for the residents in advance of the training. On the day of the lab, a brief review of current treatment practices and surgical indications for treatment was provided. Urology residents were taught and then performed the extravesical nondismembered, Cohen Cross Trigonal, extravesical dismembered, and the intravesical Politano-Leadbetter technique. In addition to these reimplant techniques the residents had additional time to practice other techniques including partial nephrectomy, transureteral ureterostomy, ureterocalycostomy, Boari flap, psoas hitch, and multiple bladder closures.

RESULTS: (Table 1) The result is a high-fidelity, low-cost, and readily available model for ureteroneocystotomy.

CONCLUSIONS: The application of innovative models for the development of surgical skills in the face of declining surgical volume of open ureteral reimplants allows for the acquisition and honing of surgical technique thereby diminishing the surgical learning curve. We will continue this lab and plan to add endoscopic subureteric injection of bulking materials and also to use the model to practice robotic ureteral reimplantation.
### Table 1: Ureteral Reimplant Lab – Resident Evaluation of Lab

Number of residents participating: 14 urology residents, 2 Med3 students
Number of evaluations returned: 16 (100%)

<table>
<thead>
<tr>
<th>Learning Objectives</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
</tr>
</thead>
<tbody>
<tr>
<td>My learning objectives were not met for this procedure</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>16 (100%)</td>
</tr>
<tr>
<td>Technical Demonstration:</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>Instructor failed to clearly demonstrate the basic principles</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>2 (12.5%)</td>
<td>14 (87.5%)</td>
</tr>
<tr>
<td>Basic principles were somewhat demonstrated, but need improvement</td>
<td>0</td>
<td>4</td>
<td>5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Practice:</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>Received no hands-on practice time</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>16 (100%)</td>
</tr>
<tr>
<td>I received some hands-on practice time</td>
<td>2 (12.5%)</td>
<td>13 (81.3%)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>I received exactly the right amount of practice time</td>
<td>4</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Confidence:</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>I would not be able to perform this procedure unsupervised</td>
<td>1 (6.2%) (I’m an intern)</td>
<td>0</td>
<td>0</td>
<td>2 (12.5%)</td>
<td>13 (81.3%)</td>
</tr>
<tr>
<td>I could perform this procedure with supervision</td>
<td>3</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fidelity of the Model:</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>Not like human in any way</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>7 (44%)</td>
<td>6 (38%)</td>
</tr>
<tr>
<td>Adequate, but needs work</td>
<td>3</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Was like operating on a human</td>
<td>4</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

NA/blank: 3 (18%)
Validation of a Novel Needle Holder to Train Advanced Laparoscopy Skills to Novices in a Simulator Environment

Ninos Oussi, MD1, Konstantinos Georgiou, MD2, Andreas Larentzakis, MD, MSc, PhD, FACS3, Dimitrios Thanatas, PhD3 and Lars Enochsson, MD, PhD4

1Karolinska University Hospital, Stockholm, Sweden, 2National Kapodistrian University Athens, Athens, Greece, 3National Kapodistrian University Athens, Athens, Greece and 4Umea University, Luleå, Sweden

INTRODUCTION: Our aim was to objectively evaluate if a newly designed needle holder (NNH) could shorten the learning curve of novices in advanced laparoscopy (AL) techniques (suturing and knot-tying) compared to a conventional market needle holder (MNH) in a simulator as well as to validate a new video scoring system to determine AL-skills.

METHODS: 46 medical students were randomized into identical tasks with either NNH (Laprotech AB, Sweden) or MNH (Karl Storz, Germany) in a prospective, cross-over study evaluating AL-skills (NNH vs MNH). All subjects performed a double-throw knot, two single-throw knots following three running sutures in the Simball box (SB) simulator. After resting, both groups performed the second trial switching NH. All tasks were videotaped and analyzed through both the SB-software and by two independent reviewers, using an Objective Video Evaluation Scoring Table (OVEST), produced by the authors. Performance of the two trials are expressed both as SB overall score (SBOS) and OVEST.

RESULTS: In both trials: a) OVEST exhibited excellent correlation between the two reviewers (RSquare 0.89 p<0.0001) b) OVEST and SBOS significantly correlated (RSquare 0.31 p<0.0001, RSquare 0.30 p<0.0002). In the group starting with NNH and followed by MNH, OVEST was consistently high during both trials (12.2±0.8 and 13.3±1.1). However, in the group starting with MNH, OVEST improved significantly when the participants changed to NNH (9.7±1.0 vs 12.7±0.8 p=0.0003) (Figure 1), an improvement also registered by SBOS (42.2% vs 49.0% p=0.0289).

CONCLUSIONS: This study shows a significant improvement and a shortening of the learning curve when novices are training in AL-skills with the NNH compared to the MNH. Our findings suggest that it could be feasible to start early AL training in novices using the NNH. Furthermore, OVEST may be used in an experimental setting as an evaluation tool, comparable with the validated software program of the SB.
Table 1.

Comparison of OVEST-scores between the New NH-group and the Market NH-group across two trials.

- **New NH-group**
  - 1st trial: ~14
  - 2nd trial: ~15
  - NS

- **Market NH-group**
  - 1st trial: ~10
  - 2nd trial: *p = 0.0003

Note: The OVEST-score is a measure of vestibular function.
INTRODUCTION: Simulation based training is known to help residents prepare for their operative experiences. However, resources are finite in most programs when creating a surgical simulation curriculum. As a result, we sought to: 1) study the preferences of faculty and general surgical residents as to which operations to include in our general surgical simulation curriculum, and 2) assess which resident skills, developed in our longstanding experiential program of learning, could be improved upon at each level of training.

METHODS: A list of SCORE common essential general surgical operations were sent to all faculty and residents and they were asked to rate each operation per its value for inclusion in the simulation curriculum. (Likert score 1-unnecessary, 5-essential). Survey participants were also asked to list their “top five” operations for inclusion in the curriculum. In addition, faculty were asked about areas in which technical skills could be improved for each level of residency using the OSATS model (objective structured assessment of technical skills).

RESULTS: Twelve general surgical faculty and 25 residents completed the survey (7 PGY4/5, 12 PGY2/3, 6 PGY1). For faculty, laparoscopic cholecystectomy (4.75), open inguinal/femoral hernia repair (4.58), and small intestinal resection (4.42) were the highest ranked operations (weighted mean Likert score). Varicose vein surgery, excision of perianal condyloma, and anal sphincterotomy were the lowest. PGY4/5s ranked laparoscopic colectomy (4.7) highest; PGY2/3 – tracheostomy and open colectomy (both 4.58); PGY1 – open exploratory lap, ileostomy, CVC insertion, tracheostomy, and temporary abdominal closure (all 4.83). Faculty identified areas for technical improvement at each resident level are shown in Figure 1.

CONCLUSIONS: These results support adopting a training level-specific approach when crafting a surgical simulation curriculum and clarify on which procedures to focus. It also supports building into the curriculum opportunities for senior residents to improve their understanding of operation flow and forward planning.
Table 1.

Faculty identified areas for improvement in technical skills

- Respect for tissue
- Time and motion
- Instrument handling
- Knowledge of instruments
- Use of assistants
- Flow of operation and forward planning
- Knowledge of specific procedure

OSATS criteria rated by faculty

- Intern
- PGY2/3
- PGY4/5
Attitude Adjustment? Impact of Simulation-based, High-fidelity Inter-Professional Team Training on Senior Medical Students’ Short-Term Teamwork Attitudes

Laura S. Bonanno, PhDc, DNP, CRNA¹, Deborah Garbee, PhD, APRN, ACNS-BC¹, Qingzhao Yu, PhD¹, Vladimir J. Kiselov¹, Jennifer E. Badeaux, DNP, CRNA¹, Jennifer B. Martin, DNP, CRNA¹, David Kalil, DNAP, CRNA¹ and Raymond E. Devlin, DNP, CRNA¹

Louisiana State University Health New Orleans, New Orleans, Louisiana

INTRODUCTION: Effective and efficient teamwork among the various professions involved in the care of a patient is essential for safe, quality care. Unfortunately, the clinical environment often harbors a degree of professional tribalism that promotes a silo mentality. Inter-professional education (IPE) can break down these silos. We investigated the impact of introducing a simulation-based, inter-professional team training program on senior medical students’ team-based attitudes.

METHODS: From January 2015 to March 2017, inter-professional teams comprising combinations of senior medical students, nurse anesthesia students, and allied health students participated in a dual scenario, high-fidelity, simulation-based training format with immediate after-action debriefing. Senior medical students each participated in one session of training. They completed the pre- and post-intervention TeamSTEPPS Teamwork Attitudes Questionnaire (TTAQ) at the beginning of their final year and before graduation, respectively. Matched mean scores were calculated for each of the five TTAQ subscales, and scores were compared within each year and between years using paired t-tests and linear regression. For the 2015 graduating class, senior students were further divided into those who underwent training from January to March and those who did not do training.

RESULTS: Matched scores for the three years were available for 174 senior medical students, of which 58 did not undergo training. Analysis within years revealed a significant decrease in mutual support among untrained students in 2015 and a significant increase in situation monitoring among 2017 students. Trends for all other subscales were mixed. Between year analysis revealed a significant increase in mean leadership scores from 2015 to 2017 and in mean situation monitoring scores from 2016 to 2017.

CONCLUSIONS: The short-term impact of a single high-fidelity, simulation-based, inter-professional team training session on senior medical students’ teamwork attitudes is nuanced. It demonstrates a limited, positive impact on certain team-based competencies and mean TTAQ subscale scores from year to year.
Experienced Surgeons Versus Novice Residents: Validating a Novel Knot Tying Simulator for Vessel Ligation

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¹Tel Aviv University, Tel Aviv, Israel, ²Sheba Medical Center, Ramat-Gan, Israel and ³Technion - Israel Institute of Technology, Haifa, Israel

INTRODUCTION: Vessel ligation with a knot is one of the most fundamental tasks surgeons must master. We developed a novel simulator designed to enable novices to acquire basic surgical skills in knot tying. We evaluated the capabilities of experienced surgeons using the simulator compared to those of residents.

METHODS: A bench-top knot-tying simulator with computer acquired assessment, developed by us, was tested on surgeons and surgical residents at an academic medical center during the years 2016-2017. Each participant tied a total of eight knots in different settings (superficial vs. deep) and techniques (one-handed vs. two hands). The knots were tied to a hook with a diameter of 0.5 cm, connected to a sensor. The simulator measured vertical forces and the time for task completion. Participants were not aware of the exact parameters assessed by the simulator. Novices were instructed to avoid tissue rupture or loose knots.

RESULTS: Fifteen surgeons with 201 years of cumulative surgical experience (13.4 ± years each) and 30 surgical residents post-graduate years (PGY) 1-2 were recruited for the study. The expert group exerted significantly less total force during placement of the knots than the novice residents (3.8 ± 2.0 vs. 9.2 ± 6.1 Newton (N), respectively, p = 0.0005), as demonstrated in Figure 1. The peak force exerted upward during placement of the surgical knots was significantly lower in the expert group compared to the residents (1.31 ± 0.6 vs. 1.75 ± 0.84 N, respectively, p = 0.02). The experts also completed the task in a shorter time (10.9 ± 3.4 vs. 18.3 ± 7.2 seconds, respectively, p = 3.4x10-5). There was no significant difference between experienced and novice participants in the maximum force exerted downwards.

CONCLUSIONS: The simulator can offer residency programs a low-cost bench-top platform to objectively train and assess the knot-tying capabilities of surgical residents.
Table 1.
POSTER ROUNDS GROUP C
SATURDAY, MARCH 16, 2019
How Well Do Dynamic Models of Teamwork in Surgical Simulations Reflect those of Live Patient Encounters?

Ronald Stevens, PhD¹, Ann Willemsen-Dunlap, PhD², Trysha Galloway³, Jamie Gorman, PhD⁴, Julian Lin, MD⁵ and Donald Halpin, MBA²

¹UCLA School of Medicine, Los Angeles, California, ²Order of Saint Francis Hospital, Peoria, Illinois, ³The Learning Chameleon, Inc., Culver City, California, ⁴Georgia Tech, Atlanta, Georgia and ⁵University of Illinois College of Medicine, Peoria, Illinois

INTRODUCTION: Our understanding of teams, and the contributions that each team member makes to the team is being accelerated by the generation of dynamic biometric and communication data streams that can rapidly detect changes in team dynamics in response to shifts in the environment and team members’ actions. This ability could lead to adaptive systems for guiding the assembly, training and support of teams in complex real-world environments like surgery. Most of the team models being developed from these data come from simulation performances, and the question arises as to how well do these models of neurodynamics and communication built at 1 s resolutions reflect the dynamics of teams during live-patient encounters?

METHODS: To approach this question we have used neurodynamic and communication models developed from ten simulated healthcare team performances to study how simulation-derived findings apply to teams’ performing in live patient environments.

RESULTS: The presentation will describe how we use these models to show that procedures and communications that superficially appear similar in simulated and live patient settings, show cognitive differences as the dynamics are observed at shorter time scales.

Table 6. Comparisons between the groups for the number of attempts taken to reach competency in the testing phase

<table>
<thead>
<tr>
<th></th>
<th>Difference in mean</th>
<th>Lower 95% CI</th>
<th>Upper 95% CI</th>
<th>t values</th>
<th>P values</th>
</tr>
</thead>
<tbody>
<tr>
<td>2 weeks vs controls</td>
<td>2.14 ± 1.15</td>
<td>-0.2328</td>
<td>4.522</td>
<td>1.85</td>
<td>0.075†</td>
</tr>
<tr>
<td>1 month vs controls</td>
<td>0.10 ± 1.10</td>
<td>3.780</td>
<td>0.414</td>
<td>5.42</td>
<td>0.0001*</td>
</tr>
<tr>
<td>1 month vs 2 weeks</td>
<td>3.96 ± 1.16</td>
<td>1.578</td>
<td>6.333</td>
<td>3.42</td>
<td>0.0020*</td>
</tr>
</tbody>
</table>

† Values shown are given as mean ± standard error of the mean
The reported P values were derived from single degree of freedom post-hoc pairwise comparisons
* = Significant
INTRODUCTION: Tendon repair (TR) is an advanced, technical skill. Proper technique is critical in avoiding complications such as rupture and adhesion. We have developed a porcine model to provide a high-quality, realistic simulation of TR for instruction and practice. This model saves cost by facilitating a second use of a commonly discarded tissue resource following use for suture training in simulation.

METHODS: Ten medical trainees who were unfamiliar with TR techniques were taught a modified Kessler, 2-strand core-suture TR using both video and in-person instruction. A diagram illustrating the TR suture pattern was provided to the participants as a reference during the simulated TR. Pig feet were dissected to expose the extensor digitorum lateralis tendons, which were then transected. Participants performed the 2-strand TR on a porcine tendon in-situ using 4-0 PDS suture. Surveys were conducted before and after the workshop to assess the participants prior knowledge, interest in surgery, confidence in surgical skills, and their satisfaction with the training model.

RESULTS: The participants reported an average increase of 36% in familiarity with TR techniques and an average increase of 24% in their confidence in their ability to perform such a TR after participating in this workshop, from 10% confidence before the workshop to 34% after. Students reported an average satisfaction of greater than 80% with the porcine model, the visualization, the tools provided, and the instruction offered as effective in teaching TR. 90% of the participants expressed great interest in participating in future surgical workshops of this nature.

CONCLUSIONS: Our low-cost, realistic porcine TR model successfully taught both the concepts and technical skills required to perform a basic TR. Nearly all participants rated this model to be an effective and appropriate teaching tool that increased their interest in surgery.
**Analysis of General Surgery Intern Performance on Simulation-Based Anatomy Examinations**

Abhishek Chandra, BA, Yazan N. AlJamal, MBBS, Fareeda Mukhtar, MBBS, Courtney M. Backstrom, BS, Aashish Rajesh, MBBS, Rafael U. Azevedo, MD, Nizamuddin Shaikh, MBBS, Mohamed S. Baloul, MBBS and David R. Farley, MD, FACS

Mayo Clinic Rochester, Rochester, Minnesota

**INTRODUCTION:** It is essential that anatomical knowledge increases in residents maturing through a general surgery (GS) residency program. A simulation-based curriculum at our institution has been effective in driving the knowledge (naming) and spatial understanding (placing) of abdominal anatomy in GS interns. However, it is unclear which particular domains of abdominal anatomy require further instruction and study.

**METHODS:** GS interns (2016-2017) were assessed in their ability to identify and place anatomical structures of the abdomen using a low-fidelity simulation model. One point (each) was given for naming and placing anatomical structures in the correct position. A standardized checklist was used to assess trainee performance before and after six-months of a simulation curriculum. A granular analysis of pre and post-test performance was conducted to determine in which anatomical regions, performance significantly improved, worsened, or had limited change.

**RESULTS:** Twenty-eight GS interns completed the abdominal anatomy assessment on both exam dates. A significant ($p < 0.05$) improvement in overall performance was observed in the naming and placing of arterial, venous, and biliary anatomy. Diminished performance was specifically noted in the naming and placing of gonadal arteries and veins, segments of the colon, and renal arteries. No improvement was observed in the naming or placing of organ structures, gastrointestinal vasculature, and nervous system anatomy. A minority of interns (19%) were able to identify or localize any nerves of the abdomen. Table 1 demonstrates some structures with high or low pre and post-test values, those with no change in performance, and those with a significant increase or decrease in performance.

**CONCLUSIONS:** GS interns showed an overall improved performance on a simulation-based abdominal anatomy assessment. Patterns of poor performance in naming and placing specific anatomy indicate areas where further instruction or repetition may be required to fill the gaps in anatomical knowledge and understanding among our interns.
Development and Evaluation of a Low-Cost Laparoscopic Cholecystectomy Simulation Model

Rafael U. Azevedo, MD, Abhishek Chandra, BA, Fareeda Mukhtar, MBBS, Courtney M. Backstrom, BS, Mohamed S. Baloul, MBBS, Nizamuddin Shaikh, MBBS, Aashish Rajesh, MBBS and David R. Farley, MD, FACS

Mayo Clinic Rochester, Rochester, Minnesota

INTRODUCTION: The formal instruction of minimally invasive surgical skills and operative insight is challenging. While low and high-fidelity simulators have gained popularity in resident instruction, they are often costly, limiting the opportunity for large numbers of trainees to practice. A low-cost simulator may be of great utility in helping learners develop laparoscopic skills and procedural insight. This project aimed to develop and evaluate a low-cost, reproducible, and reusable laparoscopic cholecystectomy (LC) simulator.

METHODS: The $17.50 simulator was built within one hour using low-cost materials: felt, Styrofoam, and cotton. Each gallbladder replacement was constructed within five minutes for less than $0.50. The simulator can be used with any laparoscopic tower and instruments. The LC model was utilized in three education sessions. Each general surgery intern (n=25) and three staff surgeons evaluated the model's function, test of hand-eye coordination, and educational merit.

RESULTS: General surgery interns (24/25=96%) agreed (n=14) or strongly agreed (n=10) that the simulator increased their understanding of the procedure and its specific considerations; one learner had a neutral response. 96% of interns (n=24) felt that the simulator effectively tested their depth perception and skill with tissue handling. Feedback was mostly positive regarding the anatomy (80%), its dimensions (96%), and the educational engagement (88%). When negative feedback was offered, it centered on the representation of laparoscopic dissection (28%) and vessel transection (24%). The simulator trained 40 learners before repairs were required. Mean operative time to complete the procedure with two interns and a camera assistant was 40 minutes (range:18-60). Surgical staff lauded learner engagement and opportunities for retention through pointing out intern mistakes made during the procedure.

CONCLUSIONS: This $17.50 reusable LC simulator with $0.50 replaceable parts shows promise in supporting general surgery intern acquisition of laparoscopic skills. Clinical instructors found the model valuable for teaching laparoscopic skills and procedural steps.
Using a Simulation Based Curriculum to Teach General Surgeons Obstetric & Gynecological Skills

Donald Delorey, PhD, Joy A. Greer, MD, Michael Spooner, MD, April McGill, MD and Rebecca Kiser, MSN

Naval Medical Center Portsmouth, Portsmouth, Virginia

INTRODUCTION: A multidisciplinary simulation curriculum was developed and implemented within a military teaching hospital to address the pressing need for obstetric & gynecological (OBGYN) procedural training for military general surgery residents. The primary goal was to increase exposure to and confidence in performing commonly encountered OBGYN procedures in a deployed setting [spontaneous vaginal delivery (SVD), Bartholin’s cyst incision and drainage with word catheter placement, Cesarean delivery (CD), and total abdominal hysterectomy (TAH)]. Objectives included 1) verbalizing steps of each procedure; 2) demonstrating the ability to perform these procedures on task trainers in the sim center with proctor feedback; and 3) discussing potential complications and mitigating techniques.

METHODS: All general surgery residents within our hospital participated in a 4-hour simulation-based session which included a targeted lecture followed by skills stations. A five-point Likert scale was used to evaluate the learner’s knowledge and confidence levels regarding four OBGYN procedures (SVD, Bartholin’s, CD, and TAH) pre- and post-simulation. The Simulation Design Scale (Student version) was used to evaluate specific features of the simulation. Data were compared with Wilcoxon rank sum test.

RESULTS: Of the 18 learners, knowledge and confidence levels significantly improved in all simulated areas (Table 1). Post curricular surveys (56% response rate, 10/18) indicated a high satisfaction with the simulation (4.9/5.0).

CONCLUSIONS: Conclusions: The implemented curriculum increased resident knowledge and confidence in four OBGYN procedures and demonstrated a high level of learner satisfaction. The curriculum can be expanded to other non-OBGYN physicians to enable appropriate OBGYN care in military environments.
Table 1.

<table>
<thead>
<tr>
<th>Procedures</th>
<th>Mean knowledge and confidence level</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(pre SIM)</td>
<td>(post SIM)</td>
<td>p-value</td>
</tr>
<tr>
<td>Bartholin's</td>
<td>1.60±0.88</td>
<td>3.67±0.94</td>
<td>0.001</td>
</tr>
<tr>
<td>SVD</td>
<td>2.87±0.81</td>
<td>3.67±0.94</td>
<td>0.005</td>
</tr>
<tr>
<td>TAH</td>
<td>1.83±0.90</td>
<td>3.22±1.23</td>
<td>0.001</td>
</tr>
<tr>
<td>CD</td>
<td>1.89±0.87</td>
<td>3.33±1.29</td>
<td>0.001</td>
</tr>
</tbody>
</table>
Feasibility of a Simulation-Based Elective in Robotic and Minimally Invasive Surgery for Medical Students

Sophia H. Roberts, Cole P. Rodman, Jared W. Squires, BA, Joshua H. Conner, BS and Michael P. Meara, MD

The Ohio State University Medical Center, Columbus, Ohio

INTRODUCTION: As robotic surgery has become more widely utilized, many residencies have begun to incorporate dedicated robotic surgery curricula into their training programs. What is lacking, however, is means for practical exposure to robotic techniques when aspiring surgeons are still in medical school. In order to address this need, we propose a month-long curriculum for fourth-year medical students containing minimally invasive and robotic components. The robotic component incorporates simulation time on the robotic operating system, bedside assistance in robotic cases, lectures on robotic techniques, and presentation of a robotic surgical case. The purpose of this study was to assess the feasibility of medical students attaining proficiency in robotic surgery simulation exercises within a timeframe that is amenable to a month-long course.

METHODS: After completing Intuitive’s modules for the Si and Xi systems and our institution’s module for operating the da Vinci Skills simulator, four medical students participated in this feasibility study. Students attempted each of the 27 exercises in the simulator catalog until attaining a passing score >90%, indicating proficiency. From these 27 exercises, we identified 20 exercises for our proposed medical student elective.

RESULTS: Students required an average of 95.3 attempts and 4.7 hours of active simulation time to complete all 27 exercises in the simulator catalog with a passing score and an average of 39.0 attempts and 2.3 hours to complete the 7 exercises in our institution’s current curriculum for general surgery residents. From the complete catalog, we identified 13 additional exercises to augment the resident curriculum to form our proposed medical student curriculum. Students required an average of 70.1 attempts and 3.5 hours of active simulation time to complete the proposed curriculum.

CONCLUSIONS: Medical students can attain proficiency in an expanded catalog of simulation exercises in an amount of time that is appropriate for a month-long self-directed elective.
Implementation of the Structured Training for Endovascular Techniques (STENT) Curriculum

Morgan L. Cox, MD, MHS, Brian Gilmore, MD, Neena Pack, MHS, PA, Uttara Nag, MD, Brandon Henry, MD, Ranjan Sudan, MD, FACS, John Migaly, MD and Chandler Long, MD

Duke University, Durham, North Carolina

INTRODUCTION: Competency in minimally invasive techniques is a requirement in general surgery training. While catheter-based techniques are increasingly critical to multiple surgical subspecialties, general surgery programs have not integrated these skills into competency-based training curricula. This study aims to identify interest in endovascular skills during general surgery residency and to implement a novel, endovascular curriculum with presentation of early experience data.

METHODS: A survey to gauge interest in developing endovascular skills during residency was distributed to 48 general surgery residents at a large, academic medical center in the Spring of 2017. Subsequently, a curriculum was developed including written materials, simulator-based training, and hands-on procedural time with vascular surgery faculty. Participants completed a survey (5-point Likert scale), written knowledge test, and simulator-based assessment before and after completing the month-long curriculum.

RESULTS: A total of 24 residents (50%) participated in the initial survey with 87.5% somewhat to very interested in endovascular training during general surgery residency. Most residents (75%) were in favor of adding angiography experience to an existing endoscopy rotation. Since implementation in July 2018, four residents (three CY2, one CY3) have completed the curriculum. None had previously participated in an endovascular case. All residents had a greater mean increase in understanding of endovascular devices (1.75 to 2.75), femoral access (1.5 to 3.5), and diagnostic angiography (1.5 to 3.25) compared to comfort level performing those same skills (1 to 2.5, 1.5 to 2.5, and 1 to 2.5, respectively). Satisfaction with endovascular training improved from 1.25 to 4.

CONCLUSIONS: Early survey data suggests this novel and comprehensive endovascular curriculum leads to a better understanding of catheter-based procedures by junior residents. This curriculum provides a foundation of knowledge that can be built upon in senior rotations. Further curriculum development will include a competency-based training program setting the standard for a national, standardized curriculum.
Table 1.

<table>
<thead>
<tr>
<th>Understanding of:</th>
<th>Mean Pre-Survey Score</th>
<th>Mean Post-Survey Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>Endovascular devices</td>
<td>1.75</td>
<td>2.75</td>
</tr>
<tr>
<td>Obtaining femoral access</td>
<td>1.5</td>
<td>3.5</td>
</tr>
<tr>
<td>Performing diagnostic angiogram</td>
<td>1.5</td>
<td>3.25</td>
</tr>
<tr>
<td>Comfort level with:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Endovascular devices</td>
<td>1</td>
<td>2.5</td>
</tr>
<tr>
<td>Obtaining femoral access</td>
<td>1.5</td>
<td>2.5</td>
</tr>
<tr>
<td>Performing diagnostic angiogram</td>
<td>1</td>
<td>2.5</td>
</tr>
<tr>
<td>Satisfaction with endovascular training</td>
<td>1.25</td>
<td>4</td>
</tr>
</tbody>
</table>

*All survey questions were answered on a 5-point Likert Scale*
Development of a Laparoscopic Trocar Placement Simulation Model: A Preliminary Evaluation

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University of Minnesota Medical School, Minneapolis, Minnesota

INTRODUCTION: Teaching laparoscopic trocar (LT) placement in the operating room would optimally occur after successful training sessions in a simulation center. Safe LT placement requires education, training, feedback, and practice. We developed an LT placement training model to compare the accuracy of LT insertion by medical student participants who were inexperienced with LT placement using two techniques.

METHODS: A novel three-layer synthetic abdominal wall model was developed to teach LT placement using a laparoscopic training box. Participants attempted to direct the LT at the center of a target placed within the training box. The laparoscope was held and operated by either an assistant (1) or by the participant placing the LT (2). Surgical drapes limited the view of the target to the laparoscopic monitor. Each participant used both techniques, and accuracy was determined by measuring the distance from the center of the target. Measurements were made by extending the free standing LT trajectory using an inserted probe to contact the target. The distance between the target center and the contact point was measured. A single investigator served as the laparoscopic camera assistant, and one blinded investigator made every measurement.

RESULTS: Seven inexperienced medical students performed the LT placement using each technique in a randomized fashion. The mean distance to the center marker was 6.0±0.7 cm when the camera was held by an assistant and 4.3±0.5 cm when the camera was held by the participant. The mean improvement in accuracy was 1.7±0.9 cm (range: -2.3 cm to 4.3 cm) when the medical student participants held the camera themselves. This difference between the two techniques did not reach statistical significance (p=0.095).

CONCLUSIONS: We developed a new model for training LT placement and used this model to test a surgical skills hypothesis. We plan to use this model to evaluate further teaching trocar technology.
A Review of Checklist Tools for the Assessment of Central Venous Catheter Insertion: Are We Using Best Practices?

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INTRODUCTION: A focus on patient safety has led many to develop and publish checklists for assessing procedural competence in central venous catheter (CVC) insertion. Deciding which of these tools to use in a local quality-improvement program is daunting, particularly given the lack of evidence as to the use of best practices in their development. The goal of this review was to evaluate current literature on CVC checklist development in light of best practices to provide guidance on their local adoption and future development.

METHODS: A literature search was conducted from 2009-2018 using keywords such as “Checklist” and “Central Venous Catheter”. Inclusion criteria included: complete description of the development/use of the CVC checklist tool; focus on insertion (not maintenance); evaluation of procedural skills beyond sterile technique. Two authors double-coded 50% of the articles. The code sheet included factors relating to checklist development and validation.

RESULTS: Of 106 potential articles, 28 met inclusion criteria. The most commonly collected validity evidence was Expert Consensus of Content (31.8%), followed by Standard Setting (27.3%), and Rater Training (13.6%). None of the studies conducted usability testing. The average number of subject matter experts (SMEs) involved in development was 4.06 ± 3.29. Almost all checklists were validated for use in a simulated environment only and the number of assessment items ranged from 17-55. Most studies (21/28) used a previously validated checklist, resulting in few unique tool development reports. Only 5 studies focused specifically on generating validity evidence for creation of their checklist.

CONCLUSIONS: Few CVC insertion checklists in the literature were developed using best practices in generating validity evidence supporting their use. Almost none have been tested in a real clinical environment. These data can guide institutions on their choice of a published CVC checklist for local quality improvement programs and encourage assessment scientists to create tools with more rigor.
INNOVATIONS IN SIMULATION-BASED EDUCATION
SATURDAY, MARCH 16, 2019
Use of a Low Cost Task Trainer for Emergency Department Thoracotomy Training in a General Surgery Residency Program

Asit Misra, MD, Alexander Chapman, MD, John O. Elliott, PhD, MPH, William D. Watson, MD, FACS, Edward Dominguez, MD, FACS and Marco J. Bonta, MD, FACS

OhioHealth Learning, Columbus, Ohio

INTRODUCTION: Emergency department thoracotomy (EDT) is a rare but lifesaving procedure. This procedure warrants deliberate practice. To fulfill this need, we developed a low-cost EDT simulator. We hypothesize that the use of this simulator to teach EDT may be more effective than a one on one discussion-based teaching session.

METHODS: A prospective 2-phase study was conducted from March 2018 to June 2018. Nine surgery residents (PGY 3-5) were randomly divided into two groups. In phase one, baseline medical knowledge for both groups was assessed using a multiple-choice question (MCQ) pretest. Group 1 was taught EDT using one on one discussion-based teaching by a trauma surgeon, whereas Group 2 used our simulator and expert debriefing for training. A posttest was given to both groups. In phase 2 (one month later), all participants completed a pretest and performed EDT using our simulator. The participants completed a reaction survey to rate our simulator and training. Two reviewers rated all participants by studying the video recordings of each scenario.

RESULTS: The mean score for performance of the procedure for the simulation-based group was significantly higher than that of the discussion-based group (Table1). The simulation-based group was quicker than the discussion-based group. For the discussion-based group the mean pretest knowledge score improved from 58.33% to 81.25% P-value 0.01(Table1). There was no improvement in the knowledge score of the simulation-based group (Table 1). The participants agreed that the simulator provided an opportunity to perform EDT and improved confidence levels.

CONCLUSIONS: The results of this pilot study support our hypothesis that a low cost simulator is effective in training EDT to general surgery residents. It provides an opportunity for deliberate practice and improves the decision-making and procedural competency of the residents as well as reduces the overall procedural time in comparison to discussion-based sessions.
Table 1.

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<th>1 (Simulation) N = 5</th>
<th>p-value</th>
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<td>Total score</td>
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<td>Total procedure time (seconds)</td>
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<td>183.5 ± 81.0</td>
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<th>Pretest Phase 2</th>
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<td>Group 2 (Simulation) N=5</td>
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Development and Evaluation of a Low-Cost Sentinel Lymph Node Model for Axillary Dissection and Biopsy

Courtney M. Backstrom, BS, Abhishek Chandra, BA, Mohamed S. Boloul, MBBS, Aashish Rajesh, MBBS, Rafael U. Azevedo, MD, Fareeda Mukhtar, MBBS, Nizamuddin Shaikh, MBBS and David R. Farley, MD, FACS

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INTRODUCTION: Performing a safe sentinel lymph node (SLN) biopsy or axillary dissection is an important procedure that general surgery residents need to master early on in their residency. Computer trainers are not yet available for these procedures and cadavers are expensive; learner repetitions and exposure to these procedures are limited. This project aimed to design, develop, and evaluate a low-cost, reproducible, and reusable simulation model for an axillary sentinel lymph node biopsy and dissection. The simulator was designed to help medical students and interns improve their skills and gain procedure-specific knowledge such as palpation, dissection, ligation of vessels, and excision of lymph nodes.

METHODS: The sentinel lymph node model was built using a variety of low cost materials: cardboard, yarn, felt, cotton, glue and memory foam. The model was created in 30 minutes and the cost was $10.00. Each skin, node, and vessel replacement for this model takes less than five minutes to construct and costs less than $0.50 each. One model can train two learners at once. Each learner (n=25) evaluated the model through survey items on anatomical accuracy, immersive simulation experience, and clinical skill representation.

RESULTS: General surgery interns (24/25=96%) agreed (n=20) or strongly agreed (n=4) that the sentinel lymph node simulator increased their understanding of the procedure as a whole and its specific considerations. 92% of interns (n=23) felt that the simulator effectively represented actual clinical skill. Feedback was mostly positive regarding the anatomical correlation (88%), instrumentation (96%), and the immersion (88%) the model offered. Negative feedback focused on the model’s inability to reproduce realistic tissue handling (24%, n=6) and vessel dimension accuracy (16%).

CONCLUSIONS: The $10.00 reusable simulation model with $0.50 replaceable parts shows great potential in enhancing intern acquisition of skills related to these surgical procedures.
Development of a Breast Abscess Management Curriculum

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INTRODUCTION: Management of patients with breast abscesses at our institution is variable, leading to inconsistent treatment and unnecessary use of resources. Our proposal aims to develop a breast abscess management training program including a didactic curriculum covering appropriate use of antibiotics, options for abscess drainage, and techniques for abscess drainage as well as hands-on training with a simulator in order to standardize treatment for our patients.

METHODS: All third-year general surgery residents will participate in a training program including a pre-survey on comfort with ultrasound guided aspiration, a didactic curriculum covering options for management including appropriate use of antibiotics, indications, and contraindications for different procedural interventions, an instructional video on ultrasound-guided aspiration, a post-didactic test requiring 100% score to pass, a training session on ultrasound-guided aspiration with a breast model, a testing session on the ultrasound-guided aspiration model, and a post-curriculum survey. Resident ability to adequately drain an abscess on a model using ultrasound guided aspiration will be assessed by a breast radiologist.

RESULTS: Resident reported comfort with the procedure and confidence in performing the procedure will be compared before and after the training. Resident ability to adequately drain an abscess on a model using ultrasound guided aspiration will be measured as percentage of abscess drained.

CONCLUSIONS: We hope to find a meaningful increase in resident comfort with and confidence in ultrasound guided aspiration of breast abscesses after participating in the training as well as evidence that participation in the program leads to the ability to effectively perform the procedure.
Teaching Burn Management Using a Low Cost Escharotomy Trainer

Asit Misra, MD, Scott Morton, MD, William D. Watson, MD, FACS and Edward Dominguez, MD, FACS

OhioHealth Learning, Columbus, Ohio

**INTRODUCTION:** Thermal burns are a significant cause of mortality and morbidity. There are about 3400 burn fatalities a year in the United States. Understanding how to manage burn patients and when and how to perform an escharotomy is critical to saving lives. Surgery residents must be trained to perform escharotomy in a timely and correct manner. Previous studies have shown limited availability of low cost simulators to teach escharotomy. We have developed an escharotomy simulator to be used by surgical residents to increase their procedural competency. We hypothesize that this low cost escharotomy simulator will be effective in training our residents to reach procedural competency.

**METHODS:** We plan to customize a commercially available, low cost human manikin by covering it with layers of artificial skin and fat. The simulator will be moulaged to mimic second and third degree burns. The simulator will be evaluated for its physical appearance, feel, and realism to mimic eschar tissue and for its functionality by completing a Likert scale based reaction survey by the learners. The learners will be assessed for their baseline knowledge by taking a pretest and thereafter they will be trained for their decision-making and procedural skills in a simulated learning environment using our simulator. After the training, the learners will take a posttest. The results of pre and posttest will be compared for improvement in learner knowledge.

**RESULTS:** Pending.

**CONCLUSIONS:** We are expecting an overall improvement in the decision-making and in the procedural competency to perform escharotomy in general surgery residents.
INTRODUCTION: Patient satisfaction has become a salient factor for healthcare institutions since it became part of the value-based purchasing metric that the Center for Medicare Services (CMS) uses to calculate reimbursement penalties. Colleague Engagement of healthcare providers with their work can contribute to the experience that patients have with their providers by creating either a positive or negative environment. Team training has been observed to have a positive effect on colleague engagement and mindfulness traits of providers has bumped the needle up on patient satisfaction.

METHODS: This mixed methods study seeks to examine the effect that training a provider and their support team, using role-play simulation based on the TeamSTEPPS platform and mindfulness exercises as a training intervention, can have on colleague engagement and patient satisfaction, as measured by Utrecht Work Engagement Scale (UWES) and provider HCHAP scores respectively, utilizing a pre-test/post-test methodology. Qualitative data was collected two weeks post-intervention as well as 3 week post-intervention follow-up focus group.

RESULTS: Eight general surgery providers and their staff were trained making a total of twenty participants. Patient satisfaction and colleague engagement scores did not reach statistical significance utilizing SPSS to calculate Pearson's r. Qualitative data indicated that participants were starting to utilize the team training concepts as well as strategies to improve patient satisfaction.

CONCLUSIONS: General surgery was initially chosen as the training group for this study as their patient satisfaction scores had not reached threshold. Just prior to the implementation of the intervention the scores had improved to above the threshold mark leaving little to no room for improvement from the intervention. Thematic analysis of qualitative data has lead to some changes in workflow due to the implementation of teamwork strategies and confirmed the patient satisfaction tools that this department had already begun to utilize.
2019 Annual ACS Surgical Simulation Summit: 
An International Multi-Professional Meeting 
Chicago, IL

Surgeons and Engineers: A Dialogue on Surgical Simulation

Pre-Conference Day - Thursday, March 14, 2019

Abstracts
DEVELOPMENT OF A MODERATE TO HIGH FIDELITY, VERY LOW-COST OPERATIVE OBSTETRICS SIMULATION TRAINING SYSTEM FOR SUB-SAHARAN AFRICA

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Drexel University Medical College, Philadelphia, PA

INTRODUCTION/BACKGROUND
The disparity between maternal mortality rates from low income/resource countries to high income/resource countries is alarming. Women living in Finland have a risk of maternal mortality of 1 in 33,333. In comparison, women living in Sierra Leone, a sub-Saharan African country have a maternal mortality risk of 1 in 74 with a lifetime risk of 1 in 41.¹

The American College of Obstetricians and Gynecologists, the Ethiopian Ministry of Health, and the Ugandan Ministry of Health invited the authors to teach healthcare providers about curriculum development, e-learning, and operative obstetrics in an effort to decrease maternal morbidity and mortality in Africa. An e-learning curriculum on operative obstetrics was completed to teach physicians and other healthcare providers how to safely perform targeted procedures while avoiding, recognizing and managing complications. As a part of the needs assessment for the online course, it was determined that present low-cost training models to teach safe performance of operative obstetrics in sub-Saharan Africa are inadequate.

The goal of this project is to develop a moderate to high fidelity, but very low-cost physical training model for operative obstetrics with a focus on cesarean sections and post-partum hemorrhage management simulations to help reduce maternal morbidity and mortality rates in sub-Saharan Africa and other low resource regions.

PAST METHODS
In needs assessments conducted over the last three years it was been determined that simulations for certain procedures could reduce maternal morbidity and mortality in sub-Saharan African countries. The procedures include:

1. Cesarean section
2. Skin closure with subcuticular sutures
3. 3rd and 4th degree laceration repair following vaginal delivery
4. Uterine balloon tamponade
5. B-Lynch procedure
6. O'Leary stitch
7. Postpartum curettage
8. Cesarean hysterectomy
9. Salpingectomy for ectopic pregnancy
10. Cystotomy repair

Very low fidelity models for several of these procedures had been previously developed. The limitations of the models included being developed for the training of only a single procedure and the models were hand-made by faculty restricting scalability. These primitive models had been constructed from mostly foam, cloth, cotton, and nylon pantyhose (Figures 1 and 2).

Although there was some value in teaching the steps of the procedures with these low fidelity models, they lack realism. In many circumstances these models provided the only training that physicians or other health care providers in Africa would receive before having to perform life-saving procedures on their obstetrical patients.

We hypothesized that creating an operative obstetrics training model that would be higher fidelity (more realistic), very low cost, and have the ability to be mass produced would provide significant benefit to trainees. This would enable higher quality and widespread training across entire targeted African countries and possibly in all low resource countries.

PRESENT MATERIALS AND DESIGN
The challenge of this project was to dramatically increase model fidelity while keeping costs extremely low. To accomplish this, a collaborative “simulation team” composed of physicians from the United States and Africa, engineers, material experts, design experts, and manufacturers was convened.

It was determined that an all-in-one model that incorporates training for all of the procedures listed above into a single model was going to be the most effective way to enhance fidelity while reducing the cost of the simulator. It was also important to create a reusable model so the trainee could execute multiple attempts for each procedure. Component replacement parts were also considered necessary for cost reduction.

The simulation team first developed some conceptual drawings to incorporate as many of the design elements as possible into a visual representation (Figure 3). The drawing included flexible and collapsible stands to foster ease of transportation and shipping, the abdomen, vagina and perineum, and postpartum uterus.

In the second phase, the structural support design drawings were modified, modularity with abdominal wall and vaginal inserts were added, and the uterus and other structures were realigned for more anatomical accuracy.

In phase three, four rounds of 3D modeling were completed, each with improvements in model measurements, realism, and relationships of anatomic structures. The second round and the fourth round of the 3D postpartum uterine model prototypes are depicted below. (Figures 6 and 7).

In phase four materials exploration was initiated. A group of experienced surgeons worked with material
experts to determine the optimal combination of silicones, urethanes, and foams for each tissue type to achieve appropriate realism while serving the project mission of cost containment.

After multiple material tests for the abdominal wall (skin with subcuticular layer, subcutaneous tissue, facia, muscle, peritoneum) uterus (serosa and muscularis), cervix, vagina, and vulva the first prototype was developed utilizing a combination of digital sculpting, hand sculpting, and 3D printing techniques. Images of the structural support and uterine physical models are shown below (Figures 8 and 9).

EVALUATION PHASE
A second prototype with cut-outs for the abdominal wall and the vagina is being developed and the resulting model will be tested in December 2018 by physicians in Uganda and by the US faculty during a 3-day hands on course. A task deconstruction of each procedure into its component parts will be completed, so the learner can then undergo proficiency-based progression training - performing each individual task to a high-level benchmark set by experts. Once a single task is mastered, other tasks increasing in difficulty and complexity are practiced and mastered.

Once all of the component tasks from a procedure are mastered, they are reintegrated so the entire procedures can be practiced, mastered, and assessed by a proctor using a checklist with binary metrics. The training process will focus on the correct execution of the procedures, forward planning, decision making and error detection to improve surgical safety and outcomes for the targeted procedures. In addition, the training process includes team training concepts and practice. Following successful completion of the training and assessment appropriate mentoring/coaching should be conducted for the first several live cases. This will ensure successful transfer of simulation skills to live procedures. This sequence is critical before granting a physician privileges for independent practice. It is noted, however, that this sequence is often difficult in low resource settings.

IMPLEMENTATION PHASE
Learnings and recommendations from the live training will be provided to the collaborative simulation team. They will make improvements in the model and it will undergo another round of field testing in Uganda in February 2019. Following any changes made after the February meeting based on objective and subjective physician feedback, molds and casts will be made for a final model in March 2019. Then the final model will be mass produced for widespread distribution in Uganda and Ethiopia. Validity testing of the e-learning program and the physical simulation model will commence in the fourth quarter of 2019.

SUMMARY
To combat the disparity between maternal morbidity and mortality rates between low income/resource countries to high income/resource countries a collaborative simulation team composed of physicians from the United States and Africa, engineers, material experts, design experts, and manufacturers was convened to develop a moderate to high fidelity, but very low-cost physical training model that incorporates the following procedures:

1. Cesarean section
2. Skin closure with subcuticular sutures
3. 3rd and 4th degree laceration repair following vaginal delivery
4. Uterine balloon tamponade repair
5. B-Lynch procedure
6. O’Leary stitch
7. Postpartum curettage
8. Cesarean hysterectomy
9. Salpingectomy for ectopic pregnancy
10. Cystotomy repair

A multi-phased project was completed that included conceptual drawings, 3D modeling, and physical model prototype development utilizing a combination of digital sculpting, hand sculpting, and 3D printing techniques. The resulting models will be tested in live hands-on training programs and improved based on objective and subjective feedback from African physicians and US faculty. Finally, molds and casts will be created for mass production and widespread distribution in Uganda and Ethiopia. Model validation will commence in late 2019.

REFERENCES
**FIGURE 1:** CESAREAN SECTION MODEL

**FIGURE 2:** B-LYNCH MODEL

**FIGURE 4:** PHASE 1 DRAWINGS

**FIGURE 5:** PHASE 2 MODIFIED DRAWINGS

**FIGURE 6:** SECOND ROUND OF 3D PRINTED UTERINE MODEL

**FIGURE 7:** FOURTH ROUND 3D PRINTED UTERINE MODEL

**FIGURE 8:** COLLAPSBILE STRUCTURAL SUPPORT SYSTEM

**FIGURE 9:** UTERINE PHYSICAL MODELS
A HYBRID VIRTUAL/PHYSICAL NUSS PROCEDURE SURGICAL TRAINER

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INTRODUCTION

Pectus Excavatum (PE) is a congenital chest wall deformity characterized by a deep depression of the sternum, occurs approximately once in every 400 births. It is often accompanied by other problems such as scoliosis, fatigue, and breathing issues [1]. In the Nuss procedure (a minimally invasive procedure to correct PE), a small incision is made on each side of the chest to insert a pre-bent steel bar from the right side of the chest to be placed and secured to elevate and support the sternum pushing out the sunken part of the ribcage. The surgeon uses a thoracoscope to monitor the procedure internally [2].

Surgical trainers and simulators have been developed for various minimally invasive procedures cultivating a rapidly growing area of research. However, a surgical simulator and trainer for the Nuss procedure has not been introduced to date. In this work describes the development of a hybrid virtual/physical Nuss procedure surgical trainer (NPST).

OVERVIEW OF CURRENT SYSTEMS

Two training platforms for the Nuss procedure were developed corresponding to either extreme of the virtuality continuum described in [3]. The purely-virtual setup couples a computer-generated virtual model of the patient and the deformity and allows the user to interact with the environment through a haptic interface. The development and initial user-validation of that system is described in detail in [4]. On the other hand, the purely-physical setup couples an adjusted anatomically correct manikin with form casted synthetic materials to allow for training using the real surgical instruments including introducers, Kelly clamps, retractors, pectus bar, and bar flippers. Adjustable springs were installed under the sternum of a generic anatomy ribcage model and replaceable molded synthetic skin and muscle were attached and fixed to the ribs. A small camera (web-cam) was mounted on a steel rod for thoracoscopy.

PROPOSED SYSTEM

The hybrid Nuss procedure surgical trainer (NPST) utilizes an optimal combination of the components of each implementation to produce a mixed-reality system that incorporates necessary physical constituents with a tailored virtual environment. This section will discuss the development of the hybrid trainer and illustrate how the system fulfills the discussed training requirements.

The Physical Module of the trainer includes a training thorax (Fig. 3a) that contains the right side of the ribcage, an articulating sternum, as well as synthetic skin and muscle. The ribs and sternum were obtained from the Visible Human Project model [5] and were adjusted, and 3D-printed, for the training thorax. The ribs were mounted on a steel rail by complementing each rib with a modeled pin that fits the rail’s openings (Fig. 1a).

The Arduino Module includes a 3-axis accelerometer and a rotary encoder connected to an Arduino Uno board. The accelerometer was mounted on the undersurface of the 3D-printed sternum to monitor its articulation and orientation at all times (Fig. 1b). The rotary encoder was installed in the hybrid pivot [6] to control the insertion distance of the surgical tool.

Within the Virtual Environment, a generic model of the patient’s torso, the Visible Human Project ribcage, a model of the pleural cavity, a generic diaphragm model, as well as developed models of the pericardium and mediastinum tissue are all influenced, with flawless synchronization, by a system of morphed deformation with a parameterized falloff. Fig. 1c shows that system for the ribcage. The degree of PE deformation (simulated via the percentage of that morphed deformation) is governed by the real-time orientation of the 3-axis accelerometer mounted on the physical sternum and connected through Arduino communication. The interior of the simulated thorax contains the 3D models of the lungs, diaphragm, and the actively beating pericardium. As the simulated surgical tool is inserted to perform mediastinal tunneling, collision models provide information used for the deformation of the lungs, pericardium, and mediastinum tissue. In order to increase the performance and produce realistic tissue deformation, the CPU-leveraged unified particle-based simulation framework NVIDIA FleX [7, 8] was utilized to create a set of clustered unified collision particles for each organ (Fig. 1d). Collisions with these particles are solved as soft bodies described with appropriate stiffness parameters and deformation models and, consequently, influence the rendering model for the corresponding organ.

The virtual environment was incorporated with a Recorder that performs automated real-time data acquisition regarding relevant metrics that describe the training session and the trainee’s performance including completion time (sec) and total instrument path (mm), the Recorder also calculates total organ collisions (number of times introducer collides with an organ (n)), excessive instrument penetration (total time introducer exceeds a given distance threshold from the center of the heart (sec)), as well as tip collisions (number of collisions between introducer’s tip and pericardial sac (n)).

RESULTS

The simulation starts with the trainee using the needed surgical instruments to make an incision at the appropriate place on the training thorax to insert
the hook of the retractor under the xiphoid process. As the trainee cranks the assembly and elevates the sternum, the simulated thoracoscopic view shows the model of the sternum moving correspondingly, relieving the formerly-depressed pericardium and making the path for mediastinal tunneling clearer (Fig. 3).

The inserts the 3D-printed surgical tool into the thorax and observes the simulated surgical introducer moving in the thoracoscopic view. The trainee then dissects the mediastinal tissue by carefully prying down on the beating pericardial sac to reach the left side and the simulation ends once the tip of the introducer reaches the exit site on the pleural cavity. The hybrid setup of the simulator, therefore, allows for realistic tactile assessment of the torso and the use of actual surgical tools to provide adequate training on the mediastinal tunneling skill (Fig. 2). The integrated Recorder measures and monitors the motion of the surgical tool and reports relevant user performance metrics.

VALIDATION
An in-vitro validation experiment was conducted to verify the functionality of the system when a particular behavior is intended. Three scenarios were executed (10 runs each) and the average performance metrics are reported in Table 1:

- **Scenario 1 – minimizing errors**: collision with any organ but the pericardial sac was avoided, excessive pressure on pericardial sac was avoided, and the undersurface of the instrument (not its tip) was used for mediastinal tunneling.
- **Scenario 2 – excessive instrument penetration**: intentional excessive penetration was applied to the pericardial sac and the instrument’s undersurface was used for tunneling.
- **Scenario 3 – tool tip perforation**: mediastinal tunneling was intentionally performed using the tip of the introducer not its undersurface.

CONCLUSION
In this work, the design, components, and rationale of the hybrid Nuss procedure surgical trainer (NPST) were discussed. Following a thorough task breakdown and analysis of the procedure, the areas where each of a virtual and a physical simulation approach adds more value were identified to create a structure of a hybrid mixed-reality training platform for the surgery. Rapid prototyping, haptic augmentation, collision modeling, and soft-body deformation techniques were utilized to construct an adequate and realistic training environment.

REFERENCES
Performance Measure | Scenario #
--- | ---
Avg. completion time (sec) | 87.1 | 106.3 | 98.3 |
Avg. instrument path (mm) | 171.1 | 159.8 | 222.9 |
Avg. organ collisions count (n) | 1.2 | 1.9 | 5.6 |
Avg. excessive penetration (sec) | 0.9 | 19.1 | 19.4 |
Avg. tip collisions count (n) | 0.7 | 9.1 | 33.4 |
ImprovEd EvIdence for Changes that Occur with Hand surgery, Treatment and/or Rehabilitation

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Background
The ability to identify improvements in hand function as a result of treatments, such as surgery or rehabilitation, is crucial. Current approaches for measuring and assessing changes in hand function have high variability, are subjective (e.g. questionnaires that ask if you can perform a task) and provide limited quantitative data. These data are also stored in a table or file that does not readily link data from repeat visits, nor are strength and motion data integrated together. Because of these factors, assessments are not easily compared across time-points. A critical need exists for a tool that quantifies changes in finger function, can relate both forces and motions, is easy to interpret (three-dimensional (3D) visual representation), and can be translated to a clinical setting.

Objective
Our work is addressing these challenges through the creation of a personalized visualization tool representing the motion and force abilities of each finger and the thumb in 3D space. This visualization tool provides numerical data as well as color-coded features for ease of interpretation. It can be used to compare data sets pre and post treatment.

Results
We will present our work thus far toward the development of this tool. We have successfully demonstrated the ability to capture accurate, repeatable 3D movement information on the hand and have demonstrated the mapping of finger forces to the motion space. Results have shown differences between populations (healthy and osteoarthritic) that can be quantified and used to monitor the progression after hand surgery. Additionally, we are examining a data set from a participant who just underwent a trapeziectomy with a button-cable suspension system.

Conclusions
As part of this summit, we would like to obtain feedback on this visualization approach and discuss with other participants their needs for evidence documenting surgical outcomes.
Simulation-based skills training is widely recognized as a potentially valuable method to improve surgeon trainees’ performance and may well become a critical element of a comprehensive curriculum in surgical education. Residents appreciate and are excited by the introduction of simulation into their education. However, many residency programs and accrediting agencies question the potentially high cost of simulation and seek reassurance that such training will provide meaningful improvements in the operating room (OR). Rigorous simulator and curriculum assessment and validation therefore provide a clear direction toward widespread adoption of simulator training. Unfortunately, paving a path in this direction requires overcoming several barriers. Each skill must be defined with sufficient clarity that exercises providing deliberate practice can be designed and performance can be measured. Surgical training opportunities in skills labs are inconsistent and poorly validated, and this needs to be remedied. Finally, the assessment of these skills in the OR must be sufficiently focused and reliable so that training gains can be observed. Starting with general observations on the status of simulation-based skills training in surgical education, this paper presents a vision for overcoming barriers to its meaningful integration in orthopaedic trauma surgical education.

VALIDATION OF SIMULATION-BASED SURGICAL SKILLS TRAINING
Gauging the validity of simulation is not a binary determination, but rather reflects a gradual judgment, depending on the purpose of the measurement and the proper interpretation of the results. A single instrument may be used for many different purposes and resulting scores may be more valid for one purpose than for another. This means that validity statements based on the evaluation of one task can be, and probably will be, different than those based on another task. Indeed, it is fundamental for creating a useful simulator-based teaching environment to recognize that a surgical procedure has to be divided into a series of steps that can be trained and measured separately.

The key to developing an effective simulator is understanding and defining specific educational objectives and the manner in which performance is measured. Gallagher argues for a paradigm shift in the way that medical professionals are trained. He suggests that proficiency is achieved through the deliberate practice of well-defined skills. Simulators, then, must be developed to serve a training regimen, and the key to that regimen is practicing to achieve a criterion performance level. Properly used, simulators are more effective than traditional training approaches, although they may be more expensive. But these extra costs may well be mitigated by yet unrealized benefits. Medical simulators facilitate novel training approaches, such as student-led learning, because the educational content can be embedded within the simulator and the training activity. They are also useful for identifying skill performance issues.

Consequently, once their benefits are fully realized, simulators may ultimately be less expensive than current training approaches, particularly if the benefits are felt in the OR and in terms of improved patient safety.

It is widely accepted that surgeons benefit from practice. The more often a surgical procedure is performed, the lower its morbidity and the better the outcome. However, practice should not be confused with repetition; performance does not improve simply because a task is repeated. The key to consistent improvement is deliberate practice combined with structured training. Deliberate practice involves engaging learners in focused, effortful skill repetition in progressive exercises that provide informative feedback. Trainees must receive immediate, informative feedback while trying to improve, and the feedback needs to match the particular characteristics of the task. Surgical skills education is beginning to benefit from these advantages as it moves toward more thoughtfully incorporating simulation in resident training. A number of commercial simulation products have arisen for skills training but assessing surgical skills in this context can be difficult, as there are few established objective metrics of performance. Although global rating scales are often used for assessing surgical skill, they do not necessarily correlate with the quality of a surgical result. Ideally, metrics of performance in a simulation should translate meaningfully into the OR.

A validated simulator can address the lack of opportunities for deliberate practice in surgical training. It can also provide residents with immediate skill feedback, an indispensable component of deliberate practice and the development of expertise. Residents need carefully devised educational variations providing incremental challenges to improve their surgical skills. The apprenticeship model struggles to control the real-world challenges faced by the residents, and feedback requires time and attention from busy staff surgeons. Simulators provide real-time feedback and instruction outside the OR, but in the end, how surgeons perform in the OR is what counts. For this reason, new approaches need to be developed to evaluate surgical competence in that high stakes environment.
RELIABLY ASSESSING SURGICAL SKILLS IN THE OR

Surgical skill can be hard to define and even harder to precisely measure. An individual skill, such as navigating a surgical wire into a specific location in a bone, is a complex interplay of task-specific knowledge, general knowledge, hand-eye coordination, team communication, dexterity, self-control, experience, and luck. It is easy to focus on the hand-eye coordination element, because that seems so unique to surgical skill compared to didactic information, but the mind tells the hand what to do, and when conducting a complex task, the mind is constantly filtering, processing, and reducing information, so it cannot be easily subtracted from the task.

Skills developed with simulator training can transfer to the OR, but the number of demonstrations of this transfer is still small. A 2013 review of the benefits and limitations of simulation in various surgical situations concluded that more evidence of transferability and improved clinical outcomes must be found before simulation can become the standard method of training and assessment. This connection between simulation and outcomes will create the opportunity to advance competency-based education.

What should be measured? A subjective evaluation from a supervisor who has a mentoring relationship with the student may be subject to a halo effect or suffer from recall bias, and such subjective measures are difficult to standardize and reproduce. What specific observable behaviors objectively constitute excellence and how do variations of these behaviors translate to different levels of performance?

These questions challenge not just medical education, but educational activities of all types, particularly activities related to simulator development. One approach to addressing them is evidence-centered design, a framework developed by the National Center for Research on Evaluation, Standards and Student Testing (CRESST 800). The approach focuses on developing models of the task, the learner and the assessment. Rather than choosing a single measure of performance, the developers build arguments that connect the task and objectives defined with respect to the domain problem, through a model of how learners assess and respond to the task as they evolve through it, then tie the assessment to key aspects of the other two models. This approach builds evidence for training validity through five sources: content evidence, response process, internal structure, relationship to other variables, and consequences. Such an approach is appealing for simulation development, because it provides a framework within which the myriad design decisions about fidelity, variability, complexity, assessment technique, and learner stage can be organized and worked together. A simulator is a representation of what the designer believes to be the essential characteristics of a task. The ideas underlying that representation are conjectures that must be externalized and tested.

This is why it is so essential to tie assessment to surgical results. Simulators have a tendency to shape thinking around the simulator’s preconceptions, wrapping the idea of a skill and the measurement of a skill in a tidy, self-contained, self-referential world. Anchoring simulator performance to surgical results raises a beacon to guide the design team out of the swirling fog of technology, preconception, and expediency.

One approach to assessing surgical skill in a clinical setting is to systematically observe objective elements of a surgeon’s behavior. Perhaps the best-known technique for this is the Objective Structured Assessment of Technical Skill (OSATS) global rating scale for open procedural skills in general surgery. Sonnadara et al. observe limitations in the OSATS method, including “being expensive, time consuming, requiring the expertise of many surgeons, and for their inability to assess a surgical procedure in its entirety.” Approaches to laparoscopic and endoscopic surgery have been more thoroughly studied. At least two methods involving global ratings and checklists are available for arthroscopy. The Arthroscopic Surgical Skill Evaluation Tool (ASSET) includes a global rating scale and a checklist of specific behaviors or tasks that should be performed. Another tool defines 45 steps in the arthroscopic Bankart procedure, along with 29 unique errors and 8 sentinel errors, steps which can then be used to objectively score a video.

These analyses compare a surgeon’s behavior against clearly defined and readily observable surgical behaviors. Anderson et al. argued that given the observational nature of its scoring, the OSATS might not effectively assess the quality of surgical results. An even more effective, albeit perhaps more difficult, strategy is measuring surgical outcomes directly to determine whether the result of the surgery matches the desired outcome. This approach is particularly powerful because it has the potential to drive behavior not towards a status quo of presumed best practice, but directly towards better surgical results. Radiographic information gathered intra-operatively can provide a measurable history of OR performance in the case of orthopaedic surgery.

Several projects have pursued the use of objective radiographic scoring as a means for assessing performance. Mayne et al. developed a model for simulated treatment of a distal radius fracture. After completing a closed reduction while video-taped, standard antero-posterior (AP) and lateral radiographs of the forearm model were obtained. Residents were rated with a checklist and with objective measurements of the radiographs, including the palmar tilt and three-point index. Putnam et al. took this approach a step further using a similar model of distal radius fracture fixation. They showed that OSATS scores had no correlation whatsoever
with the actual mechanical strength of fixation achieved. Anderson et al. found similarly that the OSATS scoring of performance with an articular fracture reduction simulation did not correlate with the quality of the reduction obtained. Grammatopoulos, et al. used stereophotogrammetry to measure the displacement of an acetabular component in a simulated surgery to study how surgeon position and technique affected their ability to accurately orient the component. Orthopaedics is clearly poised to move beyond subjective behavior assessment and build more objective assessments of surgical performance from radiographic imagery.

A CASE STUDY IN ORTHOPEDIC TRAUMA SURGICAL SKILLS TRAINING

One of the advantages of beginning with orthopedic trauma is the existing endemic use of some form of simulation for orthopaedic trauma training. The AO Foundation has been delivering training in basic fracture management using synthetic bone surrogates for more than 50 years in over 100 countries. In the United States, training is often provided by the implant manufacturers themselves using similar bone surrogates. The Orthopaedic Trauma Association (OTA) offers basic and advanced fracture care courses each year at both its Fall Annual Meeting and in the Spring, with up to 120 residents participating in each offering of the courses.

Most of the emphasis in these training courses, however, has been directed toward hands-on exposure rather than formative and summative evaluation of skill attainment. A recent review of training in orthopedic surgery cited a need for the development of standard and universally accepted measures for the objective assessment of the surgical skills of the trainees. More effective measurements made in a natural setting would help to drive the development of simulators and training programs that have a measurable impact on performance in the OR. This disconnect between simulation and natural settings is not limited to orthopedics. A review of 11,623 articles found just 33 that included both patient-based and simulator-based outcomes and the correlation between these measures. None of these papers involved orthopedics.

Utilizing generous funding from the Agency for Healthcare Research and Quality (AHRQ), we developed an orthopedic surgical simulation platform that replicates the look and feel of navigating a wire through bone utilizing fluoroscopic guidance (Figure 1). Two differentiating features of the platform are: (1) camera-based tracking of the wire replaces fluoroscopic radiation exposure, and (2) the foam bone surrogate replicates the feel of drilling through actual bone. We initially developed this platform to simulate the navigation of a wire in the treatment of intertrochanteric hip fractures. This hip fracture wire navigation simulator is currently being tested at orthopedic residency programs across the Midwest and at OTA fracture courses that are offered twice yearly (Figure 2).

While validating the simulator, we have come to deeply appreciate well-defined, sensitive, objective performance measures, because such metrics provide the best test of simulator training effectiveness and they can ultimately be linked to surgical outcomes. In our AHRQ-funded work, we have evaluated performance on the simulator, in a mock OR, and in the real OR (Figure 3). This allows us to differentiate performance improvements caused by simulator training from those improvements that accrue with experience. Subtle tests with few participants require sensitive performance measures. To maximize our yield, we have defined consistent measures that are common to both the simulator and the actual OR.

Thus far, 198 first- or second-year orthopaedic residents have participated in our hip fracture wire navigation simulator experiments, with residents drawn from four Midwestern orthopedic residency programs and from the OTA fracture courses. The task simulates placing a guide wire during the surgical repair of intertrochanteric femur fractures using a dynamic hip screw. Central to that surgery is the skill of wire navigation, which is generalizable to other common surgical procedures. In each mock OR trial, the participant uses a fluoroscope to navigate a surgical guide wire through a plastic femur, drilling from the lateral side, through the neck and into the femoral head. The wire is used to accommodate the later placement of a larger cannulated lag screw.

We assess task performance using several measures, each addressing resident skill and directly relevant to patient safety. The first measure, the tip-apex distance (TAD), evaluates the accuracy of guide wire placement within the femoral head. The TAD is measured from AP and lateral fluoroscopic images, summing the distance in each image between the tip of the lag screw to a point on the femoral head. Screws placed with a TAD > 25 mm have a higher risk of mechanical failure. The second measure of performance is the duration of the procedure; shorter durations demand economy of motion and lower the risk of infection. The third measure is the number of fluoroscopic images used in placing the wire; fewer images require a higher degree of planning and spatial reasoning from the resident and expose the resident and the patient to less radiation.

Our simulator training seems to improve performance in the mock OR. Specifically, training leads to reductions in the task duration (p=0.002) and number of fluoroscopy images used (p=0.03), building support for the simulator’s validity. Consequently, we conjecture that performance on the simulator reflects surgical skill. However, at least two important questions remain unanswered. Why do both duration and number of images decrease with training, but not TAD? Do measurements of skill in the mock OR reflect performance in a real OR? Answering these questions will require a richer understanding of orthopedic surgical skill, which will be revealed with more sensitive, quantitative, reliable evaluation.
methods. Our continuing work seeks to define such methods and to systematically apply them, for the first time, in the OR. Toward that end, we have developed consistent and reliable methods for evaluating OR performance.

EVALUATING PERFORMANCE IN THE OR
We have begun collecting videos of OR performance, along with relevant fluoroscopic images and general case data, hosting 45 cases with custom, password-protected web-server software and making them available to residents and staff. As a result of nearly two years of regulatory and technical work, University of Iowa orthopedic residents can wear a head-mounted, GoPro, point-of-view camera while performing surgery. Every fluoroscopy image collected during these surgeries is saved to the patient’s electronic medical record. Residents can immediately upload and view their videos. The fluoroscope images are superimposed on a corner of the video synchronized in time with the video, supporting the surgical narrative (Figure 3, right). In order to document residents’ surgical experience, our orthopedics department now requires residents to video record a selection of their surgeries. Residents now record at least one ankle surgery during the second year and at least one hip surgery during the third year, both milestone surgeries defined by the ACGME.3 With these data and data from our mock OR cases, we are developing protocols and quantitative evaluation techniques in order to define more precise metrics to evaluate our residents’ performance in the OR.

One study exploring our new protocols analyzed seven videos and their associated fluoroscopic images. The videos recorded seven resident surgeons placing a dynamic hip screw to fix a hip fracture. Ten raters measured the TAD for all seven cases, with a Cronbach’s Alpha of 0.97, suggesting high measurement reliability. In a related study, four raters analyzed two cases, comparing nine metrics derived from the video and fluoroscope timestamps. Four metrics were consistent for all raters and both cases: duration (from fluoroscope image timestamps), number of images, switches between AP and lateral views, and cortex head breaches. A fifth metric, procedure duration from video timestamps, produced a Cronbach’s Alpha of 0.996 and an intraclass correlation coefficient of 0.90 for single measures and 0.99 for average measures. Metrics from video analysis appear to be reliable between residents.

Although we have not confirmed that these metrics assess individual performance, duration and TAD do significantly differentiate expert from novice surgical performance. This study included 15 hip fracture cases performed by staff and residents. Task duration most strongly correlated with weeks into residency (p<0.01), a finding consistent with previous studies showing that greater surgical experience is associated with shorter operations. TAD correlated negatively with the number of previous similar cases logged by the surgeon (p=0.02), agreeing with a study in which experienced surgeons obtained better wire placement than novices.38

These preliminary findings suggest that procedure duration and TAD may be useful as objective, quantitative measures of OR performance. They are not completely satisfying, however, because duration lumps many potential causes of delay together and indirectly ascribes these delays to surgical skill. TAD emphasizes only the location of the tip of the surgical wire and neglects the wire’s trajectory through the femoral neck. Resolving these challenges leads us to a richer understanding of what constitutes surgical skill and how to best measure it.

The inadequacy of the TAD as a measure of wire placement does not only arise from its inability to measure the trajectory of the wire through bone. The inter-observer variability of TAD measurements is as high as 10%. Some of this variability is a result of uncertainty in the position of the fluoroscope and some the result of the subjective elements of the protocol used to locate the geometric reference features on the fluoroscopic images.

We are working to develop new measures of wire trajectory that leverage graphical image processing and solid modeling capabilities to express an ideal wire trajectory relative to a specific bony anatomy. Such measures can penalize wire placements that have very different starting positions or do not go through the center of the femoral neck, both of which are desirable clinical goals and indicative of a surgeon’s skill in navigating the wire. They can also help to identify poor decision-making in the course of the wire navigation. To this point, we have only used this measure with respect to our mock OR experiments (Figure 4), in which the geometry of the femur is well known, simplifying the challenge of defining the ideal wire position. However, we are currently working to refine the image processing techniques in order to define an ideal wire position in situ, leveraging our experience with similar modeling techniques.

CONCLUSION
Research efforts such as are described in this paper continue to expand the use of simulation within surgery, in general, and specifically within orthopaedics. A key challenge to the next phase of development and adoption is establishing the benefit of simulator training to OR performance. This task is challenged by the complexities of the OR.
environment. A related challenge is the difficulty of getting sufficient participants, particularly for relatively small surgical specialties, in order to provide strong statistical evidence of performance improvements. The eventual fruition of these approaches will be evidence for the generalizability of these simulation-based surgical skills training methods. Ideally, these analyses will be supported with models of the contextualized task and the learner, providing a richer support for simulator validation than can be provided by any one experiment. Experimental results will be used to enrich these models and deepen understanding of what constitutes orthopedic trauma skill. Ultimately, this new knowledge can be applied to determine which residents are ready to operate, which are ready to lead under the supervision of an attending surgeon, and which are ready for independent practice.

ACKNOWLEDGMENTS
The research included in this paper was generously supported by the AHRQ (R18HS022077 and R18HS025353), the American Board of Orthopaedic Surgery, the Orthopaedic Trauma Association, and the Orthopaedic Research and Education Foundation.

REFERENCES


**Figure 1:** The orthopedic surgical simulation platform (left) relies upon camera-based tracking of a laser-etched stainless steel K-wire (right) identical to that used in surgery. In the case of the hip wire navigation simulation shown, a foam bone surrogate is housed within a soft tissue mimicking sleeve to obscure the trainee's view of the object.

**Figure 2:** Residents training on wire navigation simulator at the OTA Fall Residents Comprehensive Fracture Course.

**Figure 3:** The current orthopedic surgical simulator (left). Performance is measured in a mock OR (center). The purpose of this project is to measure resident performance from information we've collected in the real OR (right).

**Figure 4:** Image analysis software can be used to quantify some useful metrics of the quality of the surgical result.
BUILDING A 3D MODELING PROGRAM

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BACKGROUND

A 3D modeling program refers to the capability within a healthcare organization to create patient specific 3D models within the medical decision-making pathway. Because of the complex process involved in going from medical image to 3D model, many institutions rely on industry support and one time gifts to push a case through to completion. When an institution desires to invest resources into the development of a program, the first budget targets are frequently hardware purchases such as 3D printers without considering the sustainability of a program. We aim to share our expertise around building a successful 3D modeling program by shedding light on operating budget and value of different capabilities as well as where to prioritize resources depending on the goal of the 3D modeling program.

METHODS

The process of going from medical image to 3D model is a complex workflow consisting of the following steps (Figure 1): 1. Ordering the correct imaging study that can be translated into a 3D model. 2. Segmentation: utilizing, a computer aided drawing (CAD) program, the medical image is reviewed slice by slice in 2D and the segmented anatomy is highlighted by the subject matter expert (SME). 3. Quality Control: a SME with knowledge in the medical imaging modality, and diagnostic expertise as well as familiarity with 3D model outputs must ensure that the segmented model accurately represents the findings on the medical image. 4. Content optimization, the engineering team must be able to prepare the digital 3D model for proper utilization on 3D printer(s) or in a virtual environment. 5. Clinical impact, the treating team is then presented the 3D model in physical or virtual form to complete the medical decision-making process.

The expenses to accomplish this task include hardware, software and human labor. Table 1 breaks down a general summary of our lab’s cost to initiate and maintain the 3D modeling capability for all complex congenital heart disease cases performed at the Children’s Hospital of Illinois. Not included in this estimate are external and research 3D modeling efforts.

RESULTS

The greatest expense is the annual recurring expense of the subject matter expertise. One day a week of a clinical SME and an engineering SME are estimated to be the foundation for a stable 3D modeling program of this size. The second greatest expense is in the segmentation software capability. Because we have engineering expertise spread across campuses, this number is higher due to the need for two floating licenses. If 3D printing is the desired output, there is a high up front cost as well as heavy engineering expertise utilization tied to this capability. The annual recurring expense can vary widely based on maintenance contracts and print materials (our print material cost is lower because of the type of printer utilized). Finally, if VR is the desired output, the hardware and recurring costs can be the lowest, especially if the engineer has coding expertise.

With dedicated personnel, research opportunities emerge. With the focus on streamlining the 3D workflow, research projects have generated a VR software which eliminated our 3D printing cost for surgical planning as well as an automated segmentation software which dramatically decreased the time spent on segmenting hearts. The result is that the time spent creating 3D models for clinical interaction has decreased by 82% when both elements are utilized, see Figure 2.

These efforts in efficiency enable a higher throughput of 3D models through the lab with the same effort. As can be seen in Figure 3, the number of models generated has grown since April of 2013, but with the introduction of VR and subsequently the Automated Segmentation capability into the workflow, the relative time spent for the higher volume has decreased.

DISCUSSION

The 3D modeling workflow is a complex process which requires clinical and engineering expertise utilizing complex software and hardware. When an institution commits to building a 3D modeling program, they should look first to securing the expertise which will lead the program with dedicated time combined with the engineering expertise needed for execution. The second stage of investment should be in the segmentation capability which includes hardware and software purchases. The last stage of building a 3D modeling program is acquiring the capability to interact with the 3D models created, whether this be physical 3D printed models or virtual 3D models. We have found that for surgical decision making, VR is not just sufficient, but preferred. However, the 3D printing capabilities are critical for rapid prototyping research ideas and simulations which go well beyond surgical planning. The fully functional 3D modeling program opens up many opportunities beyond medical decision making; research and product development can lead to grants, spin-offs and patents to name a few.

When considering the process of creating a 3D modeling program, investment and commitment must match the goals of the institution and not just take into account the purchase of hardware and software. Investing in people first will allow informed decision making for iterative resource utilization as a program grows.
FIGURE 1.

<table>
<thead>
<tr>
<th>Hardware/Software</th>
<th>One Time Cost (Startup Cost)</th>
<th>Human Labor</th>
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<tr>
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<td>Subject Matter Expert (SME)</td>
<td>Annual Recurring Software/Materials</td>
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<td>(~$100*/model) x 30 models a year = $3000</td>
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<td></td>
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</table>

TABLE 1.

FIGURE 2.

FIGURE 3.
VIRTUAL REALITY TRAINING FOR SURGICAL TEAMS ON THE DA VINCI SURGICAL SYSTEM: A PROOF OF CONCEPT

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BACKGROUND
Some hospitals find it challenging to train a sufficient number of operating room (OR) staff to support robotic-assisted surgeries. These challenges may arise from lack of access to the da Vinci system and/or to an instructor. While online modules can provide the cognitive training to understand how the da Vinci system works, setting up for and supporting a da Vinci procedure requires learning how to manipulate parts of the system and assess their orientations in space. Recent improvements in the cost and quality of consumer-grade virtual reality (VR) systems may provide a means to enable "hands-on" instruction and practice in a virtual environment. However, questions remain about whether surgical teams will find VR to be an acceptable and useful platform. The purpose of this project was to create a proof of concept VR module and obtain feedback from potential users.

METHODS
We created a virtual operating room and included at-scale models of the surgeon console, vision cart, and patient side cart for the da Vinci Xi Surgical System. The initial module allowed a user to deploy the patient side cart for docking and roll it up to the patient bed. Subsequent development focused on maneuvering the arms of the patient side cart, which can require large motions, (e.g., extending the arm for draping or stowing an arm), bimanual manipulation (e.g., grasping the arm with both hands to adjust a joint angle), and fine motions (e.g., instrument insertion or docking). The module was intentionally designed to include a broad spectrum of maneuver types, to assess possible limitations of manual interactions in a virtual environment. The virtual environment was run on an HTC Vive system (HTC Corporation, Taiwan) and a gaming laptop (Origin PC, Miami, FL). The Vive system is a consumer-grade, off-the-shelf system, and no customized controllers or other hardware were used.

RESULTS
At multiple points in the development process, the modules were tested by surgeons and da Vinci coordinators. Users generally adapted quickly to the virtual environment; the only person who experienced any nausea after being in VR also reported feeling ill earlier in the day. The head-mounted display did interfere with the eyeglasses of some users. Some users initially found it odd to use handheld controllers to grasp virtual objects, but they adapted quickly. Users were able to roll up the patient side cart, press buttons on the helm, insert and remove instruments, use the instrument and port clutches, and stow a patient cart arm. Feedback on the fidelity of the virtual system and how it moved was very positive. Users were generally enthusiastic about the possibility of access to da Vinci training in VR.

CONCLUSION
We have developed a proof of concept for a VR-based environment for training surgical teams on the da Vinci Surgical System. Initial feedback from potential users has been positive. Current efforts focus on designing an immersive learning experience in VR.
DEMONSTRATE PHYSICAL FIDELITY OF A 3D PRINTED AORTIC MODEL USING SPECKLE-TRACKING IMAGING

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Introduction
The use of 3D printing technology in the medical field has expanded rapidly in recent years. To allow cardiac surgeons to rehearse difficult aortic operations we have developed a 3D printed model of the ascending aorta. In this study, we sought to demonstrate the physiological fidelity of the models under oscillatory flow using speckle-tracking technology.

Methods
Two models (an aneurysmal aorta and a tubular vessel) were 3D printed using Polyjet technology with the Connex3 Objet500 3D printer (Stratasys, Eden Prairie, USA). Two different materials were used: TG P930 (a flexible material similar to aortic tissue) and a fiber-embedded material that will be used to represent local tissue remodeling that occurs with disease progression. The models were perfused with oscillatory flow representing a cardiac cycle with blood pressure ranging from 60 mmHg diastole to 140 mmHg systole. Short-axis images were obtained using 2-dimensional echocardiography. These images were analyzed using speckle-tracking (Figure 1) and the results compared to real aortic values and bi-axial tensile testing results.

Results
All models visually pulsated with the changes in the flow waveform. Preliminary results showed a correlation between values obtained from the speckle-tracking and tensile testing (Figure 2). The CCPM (Cardiac Cycle Pressure Modulus), a stiffness metric developed in our lab to classify values obtained from speckle-tracking, was able to identify the difference between the stiffer fibered and TG P930 models. The TG P930 models have similar response as in-vivo results that were previously published by our lab using speckle-tracking.

Conclusion
We have shown that our 3D printed models accurately mimic in-vivo aortic tissue using echocardiography speckle-tracking. The speckle-tracking stiffness metric also correlates positively with tensile testing results. These models have the potential to be effective tools for surgical training and for validating new strain imaging technologies.

FIGURE 1: SHORT-AXIS VIEW OF THE AORTIC MODEL USING 2-DIMENSIONAL ECHOCARDIOGRAPHY WITH SPECKLE-TRACKING

FIGURE 2: SIGNIFICANT CORRELATION OF TENSILE MODULUS (EX-VIVO MECHANICAL TESTING) AND CCPM (ECHO SPECKLE-TRACKING STIFFNESS)

FIGURE 3: SIGNIFICANT DIFFERENCE BETWEEN ANEURYSMAL AND TUBULAR MODELS
THE EFFECT OF GEOMETRY ON THE MECHANICAL PROPERTIES OF 3D PRINTED AORTIC MODELS

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INTRODUCTION

In the cardiac surgery field, there is a lack of synthetic models that can be used for surgical training that have geometric and tissue fidelity. Matching the material properties to human tissue is challenging and dependent on the geometry of the manufactured model. In this study, we took multiple 3D printed models of the ascending aorta (both aneurysmal and healthy), performed tensile testing on the models and evaluated how changing geometries affect their mechanical properties.

METHODS

Two geometric configurations of an aorta were 3D printed in two different materials: A stiff multi-material composite with embedded fibers and an elastic polymer (TG P930, a proprietary material that has similar mechanical properties to aortic tissue) (Fig 1). The tested configurations were an aneurysmal aorta and a tubular vessel with the approximate diameter of a healthy aorta. These models were tested with bi-axial tensile testing to evaluate their material properties (Fig 2).

RESULTS

Preliminary results demonstrate a difference in the tensile modulus between the two different geometries. In both cases, the aneurysmal aorta is stiffer than the tubular vessel of the same material by an appreciable margin. The result demonstrates that the geometry of the aneurysm changes the pre-stress that is created in 3D printing.

CONCLUSION

Based on preliminary results, differing geometries printed with the same material demonstrate different mechanical properties. This result will have to be taken into account in the final design of surgical training phantoms.

FIGURE 1: PRINTED ANEURYSMAL AORTIC MODEL

![Figure 1: Printed Aneurysmal Aortic Model](image1)

FIGURE 2: TENSILE TESTING OF ANEURYSM WALL

![Figure 2: Tensile Testing of Aneurysm Wall](image2)

FIGURE 3.

![Figure 3.](image3)
**STOP THE BLEED (StB): DEVELOPMENT OF A PERFUSED SYNTHETIC CADAVER MODEL**

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*New York Presbyterian – Weill Cornell Medicine, New York, NY*

**CONCLUSION**
Several training modalities are available to teach hemorrhage control techniques, varying from high-fidelity simulators, to animal models, to synthetic mannequins. In an effort to address shortcomings noted by participants in the current StB mannequin, we developed a novel perfused-bleeding mannequin that mimics both arterial and venous bleeding, responds appropriately to various hemorrhage cessation techniques, and is both inexpensive and durable.

**INTRODUCTION**
As active shootings and other mass casualty incidents have become more prevalent, courses designed to teach basic hemorrhage control to laypersons have proliferated. In the current StB course, participants undergo hands-on training using a synthetic limb mannequin. In a prior survey of 302 participants there was overwhelming sentiment that the mannequin was limited by its inability to demonstrate cessation of bleeding when hemorrhage control techniques were applied. We hypothesized that enhanced flow characteristics (pulsatile flow and flow at variable pressure) that can be stanched by StB techniques would improve the mannequin, and hence the experience and confidence of trainees.

**METHODS**
The mannequin was redesigned as a self-contained circulation model that could mimic both arterial and venous bleeding. Different synthetic soft tissues were assessed for texture, thickness, compressibility, and durability. Vessel material, construction, and placement were evaluated on their ability to mimic pulsatile blood flow and durability to repeated pressure, packing, and tourniquet applications. Multiple mechanisms of simulating blood flow (gravity, pump) were also trialed. An 85 ml synthetic rubber capacity bulb with a 7.4 mm inner diameter tubing were used resulting in a stroke volume of 16 cc per hand stroke and pressure of 20-25 kPa or 150-187 mmHg. Finally, material cost was considered to facilitate low-cost, global distribution. The final mannequin resulted in an inexpensive, novel synthetic cadaver limb model that is equipped with vessels which mimic blood flow and provide a realistic wound on which to practice the hemostatic techniques of direct pressure, wound packing and tourniquet application taught in StB.

**RESULTS**
Nurse and physician educators conducted beta testing of the perfused mannequin. One-on-one interviews revealed positive feedback regarding both realism of the perfused mannequin and participants’ ability to obtain bleeding control using StB techniques. In addition, participants who trialed the mannequin reported an increased awareness of the rate of blood flow out of a wound, which in turn increased their sense of urgency in applying hemorrhage control techniques.
INTRODUCTION

Mitral valve repair remains the gold standard treatment for severe mitral regurgitation (MR)\(^1\)-\(^4\). This has been established due to better survival rates, lower hospital mortality rates, better preservation of the left ventricle (LV) function, and greater freedom of complications (endocarditis, thromboembolism etc.), associated with repair over replacement\(^5\)-\(^6\). Repairability of the mitral valve (MV) is assessed on pre-operative transesophageal echocardiography (TEE) and is dependant upon patient anatomy, mitral pathophysiology and surgeon experience\(^3\)-\(^7\). Not surprisingly, higher volume mitral repair centres achieve better clinical outcomes and more durable mitral repairs than lower volume centres\(^8\). Even within high volume mitral repair centres, individual surgeons require a repair experience of approximately 75-100 cases to surpass the associated learning curve\(^9\).

Until now, physical models used for training in mitral valve repair have been static and limited by little if any modelling of typical pathologies. We have developed a workflow for creating physical models of patient specific pathology, derived from diagnostic TEE data\(^10\). These models can be surgically repaired and loaded into a pulse duplicator to assess repair outcomes. Our preliminary goal in this work is to develop a mitral valve surgery trainer that provides immediate feedback to the trainee regarding the success of their repair. More broadly, we are evaluating our ability to predict patient outcomes by replicating the same repair in our models as have been performed in the patient. If successful, this will make it possible for a surgeon to practice mitral repair pre-operatively, even comparing different repair options, prior to surgery. To date, we have validated our ability to replicate patient pathology and are currently validating our ability to replicate actual surgical outcomes.

METHODS

There are three main steps necessary to create patient specific valve replicas. First, the TEE image data must be segmented, the valve profiles must then be 3D printed and replicas created, and finally, the replicated valves must be tested in the pulse duplicator.

MV Segmentation

Our segmentation implements an interactive-automatic approach with limited user input required to complete a segmentation. Before performing the segmentation, the user must choose the image frame closest to systole where the leaflets are not yet coapted. This cardiac phase minimizes issues with ultrasound signal dropout while still showing two clearly distinct leaflets. Our segmentation algorithm then begins by performing a segmentation of the blood pool using a geodesic active contour approach which is biased to grow. The completed blood pool segmentation is then used to define a region of interest which initializes the leaflet segmentation. A second active contour segmentation, biased to shrink, is applied to the leaflets until the user is satisfied with the results. The active contour segmentation steps in our algorithm use an interactive-automatic approach as they require the user to run the automatic segmentation algorithm in increments until they judge the segmentation to be complete. This interactive approach proved to be more effective than a fully automatic approach, as choosing a fixed stopping point led to inconsistent results since there is inherent variability in the ultrasound images taken from different patients.

In addition to defining the surface geometry for the MV apparatus, our application requires translating this information into a polydata format capable of being 3D printed and integrated into our pulse duplicator. To this end, the leaflet surface that is proximal to the TEE source is isolated, and normals for its polydata surface are inverted to create a model of the "en face" view of the valve, including as much of the LA wall as is in the TEE field of view. This new polydata surface is then cropped with a base that matches the 3D printed valve flange.

Replicating Valves in Silicone

The workflow for creating valve replicas is described in detail in our previous work\(^10\). In summary, the segmented surface of the patient MV is 3D printed and fitted into a tray in which silicone is poured. Gauze fabric is cut to the shapes of the anterior and posterior leaflets, infused with silicone and then painted onto the 3D printed valve profile. Without gauze, silicone lacks the tensile strength of the leaflets, and sutures or clips would easily dehisce under the load of normal human hemodynamic pressures. In addition to gauze, a braided nylon thread is frayed and embedded into the silicone to replicate a total of six chordae tendinae, which further divide, imitating the human anatomical equivalents. Braided nylon adequately mimics both the flexibility of the chordae, as well as the strength required to operate under realistic hemodynamics. Using Spaceclaim CAD software (ANSYS Inc., Canonsburg, USA), the posts for the papillary muscles are tailored to accurately represent the location of the papillary tips as defined our segmentation software using the patient’s TEE ultrasound data. These papillary posts are 3D printed and fitted to the flange assembly for the MV. The two posts each incorporate three shafts.
Mitral Valve Simulator (MVS) Pulse Duplicator

The overall design of the MVS device is intended to provide a high-fidelity representation of the in vivo, dynamic MV environment that is also easy to operate and inexpensive. In brief, the pulse duplicator consists of a motor assembly and diaphragm for mimicking the contractile left ventricle, a two chambered box, and an aortic outflow tower (Figure 1, left). The valve assembly (Figure 1, center) mounts inside the high-pressure chamber. An opening in the valve assembly connects directly to an aortic outflow tube with a ball valve and spring, which provide a resistive force to approximate LV afterload pressures. Adjusting the tension on the spring changes the systolic pressure. The spring structure is housed inside a larger tube that is open to the low pressure (atrial) chamber. The height of water or blood mimicking fluid in this outer tower mimics left atrial pressures. By adjusting the spring size and tension, the MVS can create systolic ventricular pressures of over 200 mmHg, while the aortic pressure is 10 mmHg when a competent valve in installed.

The lid of the device incorporates six columns which have individual external dials and align with the six posts to which chordae tendinae are attached (Figure 1, right). This makes it possible for the user to interactively adjust individual chordae lengths to best match patient pathology, as seen in TEE Doppler imaging, while the device is in operation. Alternatively, neo-chordae lengths can be adjusted to evaluate the effect that lengths have on valve performance and hemodynamics.

RESULTS

Our first validation study used an earlier model of a pulse duplicator and involved replicating patient pathology from a dataset of ten patients who underwent surgical repair. All ten models were then repaired by an expert cardiac surgeon (Figure 2), and the repaired valve was assessed using Doppler ultrasound (sample images, Figure 3). More recently we have completed our first study using the new MVS pulse duplicator with data from six patients who either received or were considered for a transcatheter MitraClip procedure. In both studies, results have shown no statistically significand differences between our replicas and patient anatomy or pathology.

CONCLUSIONS

We present a workflow for creating patient specific mitral valve models capable of undergoing realistic surgical repairs, and a pulse duplicator for assessing the success of these repairs in a realistic hemodynamic environment. Our goal is to provide cardiac surgery trainees with a method of practicing mitral valve repairs on realistic pathology models, and immediately assess their repair in a realistic hemodynamic simulator. Beyond this, we hope to provide sufficient high-fidelity, patient specific models for procedure planning prior to complex mitral valve repair.

Disclosure: Daniel Bainbridge, John Moore and Terry Peters are co-owners of Archetype Medical, developers of the MVS pulse duplicator.

REFERENCES

**FIGURE 1:** LEFT, THE MVS PULSE DUPLICATOR; CENTER, THE VALVE AND CHORDAE APPARATUS; RIGHT, THE APPARATUS INTEGRATED IN THE SIMULATOR.

**FIGURE 2:** VARIETY OF REPAIRS PERFORMED ON MODELS; I) ANNULOPLASTY RING BEING PARACHUTED DOWN ONTO MODEL; II) NEOCHORD LOOPS PLACED ON SILICONE VENTRICLE POSTEROMEDIAL PAPILLARY MUSCLE; III) ALFIERI REPAIR COMPLETED ON MODEL; IV) SUTURING THE POSTERIOR LEAFLET.

**FIGURE 3:** I) PRE-REPAIR MODEL IN PULSE DUPLICATOR; II) PRE-REPAIR MODEL 3D DOPPLER; III) MODEL POST-ANNULOPLASTY AND NEOCHORD CONSTRUCTION REPAIR; IV) POST-NEOCHORD MODEL 3D DOPPLER; V) MODEL POST-ANNULOPLASTY AND TRIANGULAR RESECTION OF P2; VI) POST-RESECTION.
Task-Based Automated Performance Metrics (APMs): An Opportunity to Deliver Personalized, Intraoperative Feedback to Surgical Trainees

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Shortened surgeon learning curves would have tremendous impact on patient care and hospital efficiencies. In order to address this opportunity, many training technologies have been proposed and continue to be developed to supplement in-person expert feedback, such as virtual reality simulation, inanimate exercises, expert case observations, and telementoring. Additionally, many research teams have worked toward quantifying learning curves and their impact on outcomes using the conventional measures of surgery time or surgeon case volume. However, improvements and innovations are still needed to further personalize surgical training and thereby shorten learning.

One recent innovation seeks to improve the ability to quantify surgeon efficiency intraoperatively through task-based, automated performance metrics (APMs) [1]. APMs leverage the unique data stream of robotic-assisted surgical platforms to compute efficiencies related to instrument and hand controller movements, camera use or visualization, and energy use for each step of a surgical procedure (see Figure 1 for an example of Endowrist usage across steps of a robotic-assisted radical prostatectomy). In this way, APMs provide more granular and targeted metrics than conventional surgery time, which can be used throughout a surgical trainee’s training pathway.

In this abstract, we discuss several exciting opportunities for how APMs can be used to improve surgeon training. First, APMs can be used to help identify the most critical steps of surgery as they relate to outcomes or overall operating room efficiency [2]. This could be used to help focus the development of training interventions and technologies so they have the most impact on patient care and/or hospital efficiencies. Second, intraoperative assessment using APMs could be used to measure a trainee’s camera use or wrist articulation during the vesiculo-urethral anastomosis of a prostatectomy. If the APMs indicate a deficiency, the trainee can be prescribed particular simulation training exercises to complete or a unique set of surgical videos to review to address those particular aspects of her performance. Finally, APMs can be used to align assessments across intraoperative and virtual reality training. The same (or similar) APMs as those shown to be important for intraoperative, clinical tasks can be used to score procedure-specific, virtual reality training exercises. Such an approach would ensure trainees receive consistent feedback across training modalities as well as feedback known to be important for delivering the best patient care.

In summary, APMs from robotic-assisted surgery offer a new and promising opportunity to quantify surgical efficiencies and add to the growing set of training technologies that is essential to continue to improve surgeon training and patient outcomes.

References


Automated Performance Measures (APMs) | Instrument motion tracking metrics and system events (task duration)

**Figure 1:** Illustration of one automated performance metric (APM) – Endowrist usage – across 13 steps of robotic-assisted radical prostatectomy. Red indicated resident, green indicated fellow, and blue indicated attending surgeon.
Utilizing In-Hospital Fabrication to Decrease Simulation Costs and Increase Fidelity

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BACKGROUND

Two restrictive factors for surgical simulation are the cost of high-fidelity simulation and access to simulation materials and consoles. Commercial surgical simulation models continue to maintain high prices with minimal to moderate fidelity. Literature describing non-commercial simulation models remain scarce.

METHODS

Using UTMB’s MakerHEALTH® fabrication lab, which is the first of a kind in American hospitals, we have developed a gallbladder simulation model with higher fidelity than the equivalent commercial models for approximately one-tenth of the cost. By using a combination of digital and manual fabrication techniques such as 3D printing and basic mold making methods, we were able to create high fidelity gallbladder, liver, and common bile duct models for use in cholecystectomy and choledochoscope simulations, respectively. We are currently improving the production techniques for the consistency, plasticity, and tactile sensation of the materials for reproducibility at other sites.

RESULTS

The initial startup costs for our group’s cholecystectomy model (excluding currently existing laparoscopic instruments/trainer box) are approximately $70. Using a modular approach, we were able to decrease working time to 20-30 minutes upon subsequent model iterations (this could be decreased further with assembly line type production) with an approximate per use cost of $10 per use compared to approximately $100 per use in commercial models.

CONCLUSION

We believe that surgical simulation should be inexpensive and easily accessible. We describe methods for the creation of modular, cheap, and high-fidelity simulation models for widespread use with the aim of decreasing the level of entry and improving physician surgical skills. In addition, with this model, resident access to simulation is improved due to the simplicity of the model creation with the ability to create their own model at any time.

Lastly, we believe the initial investment of a fabrication workspace can not only improve simulation for all realms of medicine and therapy, but also have financial benefits in the long term.

Funding: T32GM008256-28
We are interested in continuing the dialogue between surgeons and engineers to create meaningful and extensible training tools useful for the surgical education community.

The skill of a surgeon is critical to successful patient outcomes. A recent landmark study reported that surgeons’ skill ratings were significantly correlated with clinical outcomes after surgery. A number of studies have demonstrated that medical errors caused by unskilled surgical maneuvers lead to potential medical complications and adverse patient outcomes. One way to reduce medical errors—now the third leading cause of death in the US—is to focus on effective and efficient methods to train surgical skills of clinicians.

To respond to the challenges being faced with training the next generation of vascular surgeons, the Vascular Surgery Board along with other vascular surgery educators have developed a set of core skills for open vascular surgery called the Fundamentals of Vascular Surgery (FVS) consisting of five skills—knot tying, radial suturing, anastomosis (end-to-end, end-to-side), ligation and hemostatic techniques—performed on bench models with synthetic materials towards measuring resident performance. These set of exercises are modeled after the Fundamentals of Laparoscopic Skills curriculum, used for credentialing general surgeons who perform laparoscopy. There are several limitations of the FVS curriculum, however: rudimentary outcome metrics, lack of robust feedback for skills training and correlating simulator and Operating Room (OR) performance.

Over the past several years, our team has collaborated with the creators of the Fundamentals of Vascular Surgery curriculum to create an instrumented simulator that measures vascular suturing skill. Metrics on our simulator platform measure key aspects of skilled vascular suturing: needle movement, tear forces, needle driver motion and hand movement. These metrics provide a rich set of event-specific, multi-modal and real-time metrics for assessment of vascular suturing. Initial validation demonstrates that the simulator metrics can differentiate between resident and attending suturing skill including suturing in a simulated cavity (at depth).

The goal of our work is to provide the vascular surgery community with training tools that quantify skilled performance on vascular suturing, accelerate training and correlate metrics for transfer of training to the OR. To achieve this, we use state-of-the-art sensors (force, motion and video) and data analysis techniques for skills training.
RAPID PROTOTYPE OF PEDIATRIC PEDAL ARTERIAL LINE

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BACKGROUND
Although the radial artery is most commonly used for cannulation, the risk of complications is magnified in infants and young children. Alternatively, arterial lines placed in the foot, either in the dorsalis pedis artery or the posterior tibialis artery, can be used to mitigate the risk of infection and dislocation for this demographic.

There are unique challenges associated with cannulation in children. This is especially true in the foot, which presents small arterial diameter and patient positioning limitations. With no simulator currently available, the Clinical Simulation Center (CSC) Innovations team of biomedical engineering students collaborated with pediatrics faculty to create a novel simulator prototype. We describe the process below.

METHODS
Working with pediatrics faculty, the CSC Innovations team were committed to developing an anatomical foot model that could be used to practice placing foot arterial lines in both dorsalis pedis and posterior tibialis arteries with ultrasound guidance.

For the simulator, the foot bones and foot cavity CADs were imported from the internet (open source). Autodesk® Fusion 360™ was used to modify the bones and create the foot mold to be approximately 13 cm in length, representing an average 2-3-year-old. The molds and bones were printed in BCN3D Technologies© Polylactic Acid (PLA) filament on a Digilab DREMEL© Idea Builder 3D Printer. The mold was printed in two halves divided vertically (Figure 1). The bones were printed in three sections and held in place in the mold using wire (Figure 2). To create the model “soft tissue”, the mold was filled with 00-30 Ecoflex silicon (Smooth-On, Macungie, PA). Cellulose was added and desiccation performed to allow location of arteries via ultrasound. A completed prototype is found in Figure 3.

BUILD CHALLENGES
Artery. In the first iteration, the arteries were modeled with wire that was 1.5 mm in diameter to best replicate the diameter of the pediatric arteries (range = [0.5-1.0] mm in diameter). The wire was removed after the model cured to leave cavities for blood flow. However, 1.5 mm proved too small and the cavities collapsed when the wire was removed.

Positioning. We encountered the problem of finding a realistic resting position for the foot. Each doctor consulted on this build had a unique preference for foot positioning. The silicon makes flexure possible, but it has been a challenge to find the positioning that best suits the techniques of the majority of doctors.

Blood pressure. Sustaining a realistic blood pressure is difficult in an artificial artery of such a small diameter. The typical arterial blood pressure in a child aged 1-3 is 50-55 mmHg of pressure (Elseed, Shinebourne, Joseph, 1973). This would be a challenge to achieve artificially. It is likely we will have to compromise the realism of the blood pressure.

NEXT STEPS
In the next iteration, we will try tubing measuring 2 mm in diameter to simulate the arteries. There are three notable limitations of this design. The first being that the plastic outer layer is not a realistic substitute for arterial walls with discrepancies in both width and material. Secondly, manufactured tubing requires excess force to puncture because it is thicker than pediatric arteries. This compromises the realism of the simulation and may promote damaging techniques. Lastly, the same limitation of creating realistic blood pressure will still be present because of the small diameter.

REFERENCES
FIGURE 1: ONE HALF OF FOOT MOLD.

FIGURE 2: THREE SECTIONS OF THE BONES AS THEY ARE PRINTED.

FIGURE 3: COMPLETED MODEL PROTOTYPE WITH WIRE FOR ARTERY STILL IN PLACE.
EVALUATION OF COMPLEMENTARY HAPTIC AND AUGMENTED REALITY SIMULATION IN NEONATAL THORACENTESIS TRAINING

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1Children’s Hospital at the University of Illinois at Chicago; 2Department of Biomedical and Health Information Sciences; 3Department of Bioengineering, University of Illinois at Chicago

HYPOTHESIS/RESEARCH QUESTION/OBJECTIVE

Neonatal thoracentesis, or chest-tube insertion, is a life-saving invasive procedure performed for the emergent treatment of clinically symptomatic pneumothorax or pleural effusion in neonates. Competence in this procedure is critical for practitioners who take care of critically-ill infants.1,2,3 The procedure requires intense training that can be achieved using simulation, without increasing risk to patients for potential complications from improper insertion such as bronchopleural fistula, lung puncture, injury to intra-abdominal organs (such as liver), and injury to major vessels resulting in bleeding4,5.

Virtual reality (VR) simulation with haptic feedback could provide important tactile experience to simulate the real clinical experience that may not be available through the traditional manikins or animal models currently used for thoracentesis training. Additionally, the VR model could present accurate anatomical dimensions of the thoracic space of a neonate and provide objective measurements of performance and feedback to the participant prior to operating on live infants6.

We hypothesized that the VR-based neonatal thoracentesis 3D models present accurate anatomical features and tactile feedback to simulate a real-world experience of performing the procedure.

MATERIALS AND METHODS

Model Development

Segmentation of an infant chest wall was obtained using Materialize Mimics, using data from de-identified CT and MRI scans provided by the Department of Radiology at the University of Illinois at Chicago. The pertinent layers included skin, fat, fascia, intercostal muscles, ribs, and pleura. The resulting 3D model of the upper torso, arms, and head of an infant was made using Pixologic ZBrush and Autodesk 3DS Max. The training tool included correct positioning of the model at the appropriate degree from the surface (bed), positioning for the arm, and a means to insert the instrument using landmarks of the mid-axillary line and the fourth to sixth intercostal space. Appropriate tactile feedback was provided using resistance on the haptic device when the chest tube was inserted through the layers into the pleural space. Different haptic properties were assigned to the corresponding 3D models of the anatomical layers involved in the surgical procedure.

Testing

The haptic neonatal thoracentesis training tool was evaluated by neonatal practitioners (fellows in training and practicing neonatologists) during a 2-hour session at the American Academy of Pediatrics (AAP) District VI Association of Neonatologists Annual Meeting in September 2018, to determine whether the model will make an effective means for preparing residents and nurse practitioners to improve their psychomotor skill and anatomical knowledge prior to performing this procedure in a clinical situation. Participants identifying themselves as fellows or faculty, performed simulated thoracentesis on the VR platform and completed a questionnaire evaluating the model. The previously validated qualitative survey was used to determine whether users find the simulation to be a realistic replication of the anatomy and procedure.

Analysis

A Likert-scale was used to evaluate responses to the questions on the survey. The scale ranges were as follows: 1 – not at all, 2 – somewhat, 3 – fairly, 4 – very and 5 – extremely. Means and standard deviations were utilized to analyze responses.

RESULTS

A total of 13 providers (8 neonatology faculty and 5 neonatology fellows) participated in the simulation session. Tables 1 categorizes participants’ current title and summarizes their qualitative feedback provided in the surveys completed after the pilot session. Participants’ comments about their experience during the workshop are shown in Table 2.

CONCLUSIONS

1. Overall, a high level of satisfaction was achieved in terms of the quality of the training tool.
2. Neonatology faculty considered themselves highly skilled in this procedure but less familiar with the haptic device. They rated the haptic tool highly in its utility to enhance training, anatomical orientation/accuracy, and ease of usage and entry into the pleural space.
3. Neonatology fellows, although considered themselves relatively less skilled in the procedure, rated the tool similar to the faculty.
4. Areas for improvement included ability to differentiate between layers and addition of some features to enhance the model as mentioned above.
5. Participants reported benefits from the simulator, through better understanding of the anatomy, location of the instrument within the thoracic cavity, and realistic
experience provided by the haptic resistance simulating puncturing anatomical layers.

Further investigation on the benefits and limitations of the simulator with a larger number of participants will be performed in future.

REFERENCES

![Table 1: Evaluation of the Simulator](image)

<table>
<thead>
<tr>
<th>Qualitative feedback by faculty members and fellows (mean +/- std dev)</th>
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<tbody>
<tr>
<td>Were the size, orientation, and shape of the instruments correct?</td>
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<td>How useful would the simulator be for enhancing training of neonatal chest tube insertion?</td>
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<td>How easily have you learnt to interact with the simulator?</td>
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<td>How well were you able to access the pleural cavity?</td>
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<td>How well were you able to haptically differentiate tissue stiffness of the virtual models of skin, lungs, and bones?</td>
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<td>How well were you able to identify correct position and orient the baby?</td>
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<td>Was the exploration of the anatomy intuitive for you?</td>
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<td>How well were you able to explore the anatomy of the virtual model using the simulator?</td>
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<td>Was the baby anatomy modeled correctly?</td>
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<td>How familiar are you with haptics-based virtual reality simulation?</td>
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<td>How familiar are you with neonatal chest tube insertion?</td>
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<tr>
<th>1: Not at all</th>
<th>2: Somewhat</th>
<th>3: Fairly</th>
<th>4: Very</th>
<th>5: Extremely</th>
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</table>

**TABLE 1: Evaluation of the Simulator**

<table>
<thead>
<tr>
<th>What features would you like added to the model?</th>
<th>Do you have any other suggestions?</th>
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<tbody>
<tr>
<td>“Seems that it would be helpful for technique, but the other part of practicing w/ equipment is connecting to the water-seal vacuum, suture, etc.”</td>
<td>“So cool”</td>
</tr>
<tr>
<td>“It would be cool to use finger first to palpate the difference and find landmarks before using the scalpel”</td>
<td>“This is awesome”</td>
</tr>
<tr>
<td>“A little more sensitive to piercing the skin Pigtail catheters and safety catheters in use without trocars”</td>
<td>“Not clear skin vs. pleural space entry”</td>
</tr>
<tr>
<td>“Blood vessels under ribs to know where not to go Syringe showing release of air skin incision”</td>
<td>“Wonderful”</td>
</tr>
<tr>
<td></td>
<td>“Great teaching tool”</td>
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**TABLE 2: Comments provided by the participants**
QUANTITATIVE EXAMINATION OF INTUBATION FORCES TO DEFINE PRESSURE_THRESHOLDS

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PURPOSE
In this ongoing study, flexiforce (Tekscan, ZFLEX A201-100) sensors are used to measure the amount of force obtained when using an intubation blade to 1) allow better techniques to occur with less force being applied and 2) define a threshold of pressure that should not be exceeded when doing intubation.

METHODS
Two 100 pound flexiforce sensors are attached to the intubation blade. The piezoresistive properties of the sensor result in a change of resistance when pressure is applied. A change in voltage throughout the circuit was measured and calibrated as a unit of force. Then we took the blade and recorded individual trials at the proximal and distal points of the blade. Furthermore, we recorded trials with both sensors on the blade recording simultaneously.

RESULTS
We were able to integrate these force sensors on our 3D printed, size three, intubation blade and get live feedback of the force versus time using Arduino. The blade was held in position with the force applied to acquire clean data. Circuit and device was interfaced in real time using Arduino software.

CONCLUSION
The results of the Fuji paper (FUJIFILM, CP48S) trials allowed us to place the sensors in the correct positions for readings on the blade. Seen in figure 1 (Right), it allowed us to place one sensor on the distal end of the blade and one more proximal to the handle. These two sensors were then interfaced with corresponding circuitry and software to acquire force data. This helped us to define a high and average threshold for intubating. As this research is ongoing, future improvements to streamline the instrumentation will be made.

**Figure 1:** (Left) Force of intubation on simulation dummy. (Right) The setup of our 3D printed blade and circuiting.
A NEW LEARNING MANAGEMENT SYSTEM FOR SIMULATION

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BACKGROUND

Simulation-Based Medical Education (SBME) is becoming a routine educational intervention to train healthcare professionals and healthcare professionals with skills and competencies required for their discipline and maintenance of licensure. [2] SBME provides a mechanism to instill cognitive, psychomotor, behavioral, leadership, teamwork, and communication skills.

There is currently no standardized mechanism for delivery and assessment of medical simulation. Currently performance during SBME is evaluated using pass/fail metrics coupled with debriefing following simulation scenarios. The lack of granularity in evaluation and assessment of learners makes it difficult to characterize effectiveness of SBME curricula and to determine whether skills acquired during simulation transfer to real world clinical operations.

METHODS

To address the needs and current limitations of SBME discussed above faculty and researchers at the University of Toledo (UT) have developed open-access multi-tiered cloud-based learning management system (LMS) PREPARE, that supports PREdiction of Healthcare Provider Skill Acquisition and Future Training Requirements. PREPARE was built based on evidence-based SBME guidelines and transforms the current process for creating and administrating SBME in an intuitive data-driven platform.

PREPARE consists of a web/mobile application that: 1) allows instructor, simulation technicians, and faculty to plan and create a goal-oriented SBME curriculum in a digital format, which includes curriculum goals/objectives, customizable pre-assessment and post-assessment forms (to determine baseline and post-SBME knowledge and skills). 2) the ability for faculty and educators to collaborate and share SBME curriculum and simulation scenarios with other institutions and organization. 3) the ability to define simulation scenarios consisting of learning events that are mapped to specific skills, and curriculum goals/objectives to be trained, 4) capture and track quantitative performance ratings and feedback from instructors across learners as they participate in SBME overtime 5) collect objective physiological measures related to performance, skill acquisition, and stress of learners throughout participation in a SBME.

RESULTS

A small pilot study has been completed at the University of Toledo’s Interprofessional Immersive Simulation Center (IISC) using PREPARE to evaluate its capabilities across learners from the Department of Emergency Medicine and Toledo Fire Department Paramedic Program. Currently PREPARE is in the process of being rolled out across all academic Departments within the the University of Toledo’s College of Medicine and Life Sciences. The Departments of Anesthesiology and Surgery will be participating in the next series of pilot testing at UT. Up-to-date results will be presented at the meeting.

CONCLUSIONS

PREPARE was developed with the lofty goal of standardizing delivery and assessment of SBME. It was designed with a "measuring it all" approach and provides a level of quantitative and qualitative assessment of SBME that has not been achieved to date. The goal is to provide PREPARE as an open-source platform that is accessible by any institution that wishes to adopt it. A beta version of PREPARE is currently hosted on Amazon Web Services to bring this goal closer to reality. PREPARE and its various features and functionalities are being updated and improved upon by faculty and researchers at UT.
CONSTRUCTION OF A GYNECOID BONY PELVIS TASK TRAINER FOR OPERATIVE CESAREAN DELIVERY

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ABSTRACT
High-fidelity simulation has been shown to provide invaluable learning experiences for a variety of different medical procedures.1 Currently, there are limited number of structural pelvic models that allow for realistic task training of obstetric procedures, including operative deliveries. Of the four pelvis types described in women (gynecoid, anthropoid, platypelloid, and android), the gynecoid occurs most commonly in women, yet the android configuration is the most prevalent type encountered in simulators. The common android model, composed of a resin polymer, has a number of limitations that preclude its use in obstetric procedure simulations such as cesarean sections. One restriction includes an inadequate triangular anterior segment that prevents descent of fetal vertex or breech deep into the pelvic inlet.

Another constraint encountered was inept two-point anchoring of the inferior bony pelvis which led to torque and fracture of the symphysis pubis while performing difficult extractions.2 Construction of a frame in which to reproduce the gynecoid bony pelvis, was undertaken to address the previously mentioned restrictions of the android pelvis, which is the least common anatomy seen in women. The pelvimetry of the original model was altered by increasing the oval transverse diameter of the pelvic inlet by 20% and increasing the subpubic angle from 50° to 90°. Expansion of the antero-posterior diameter was also accomplished by 20%. This increase in the circularity of the transverse ellipse of the pelvic brim will allow for the realistic simulation of the descent of the fetus into the mid pelvis and subsequent rotation into the vertex occipitoanterior position or breech presentation.3 In addition, prominent sciatic spines were filed flat to more accurately reproduce the gynecoid or “true female pelvis”. Finally, a four-point stabilization structure was added to the modified pelvis to withstand the normal forces and torque exerted on a female pelvis during cesarean deliveries. Future applications for this prototype include constructing a common female mold, which will allow for widespread distribution of this gynecoid pelvis frame that can be used to practice simulated obstetric procedures in medical education and training.

REFERENCES
Colonic endoscopic submucosal dissection (cESD) is a useful treatment modality for managing selected benign and T1 colorectal tumors, with the potential to replace endoscopic submucosal dissection (EMR) or surgery. Adoption of cESD in the West, however, has been limited given technical demands, risks of complications, and no readily available safe clinical construct for rehearsal (e.g., in Japan, mastering gastric ESD is a pre-requisite to learning the more difficult cESD). A computer-based cESD simulator could enhance safe adoption of this procedure with the potential for thousands of patients to avoid surgery per year in the US alone.

Our group has used best practices in curriculum design and procedural assessment to create a comprehensive training pathway in cESD for practicing endoscopists. This work includes development of a defined list of procedural steps for “standard” cESD and creation of an assessment tool for providing formative and summative feedback on the technical performance of cESD (MECAT – MITIE ESD Competency Assessment Tool). We would like the opportunity to collaborate with engineers to use these constructs as the basis for creation of a cESD simulator that can be incorporated into ours or other’s comprehensive training curriculum.
ASSESSMENT OF INNATE APTITUDE FOR SURGERY IN UNCONDITIONED MEDICAL UNDERGRADUATES

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BACKGROUND
Although ability for technical skills is not currently a component of the selection of surgical residents, there is a common belief amongst program directors to recruit preferentially candidates with the necessary level of innate ability for acquisition, on completion of training program, of the manipulative technical skills required by competent safe surgeons. The study assessed a large cohort of medical students for their innate level of innate psychomotor skills using a virtual surgical simulator.

METHODS
A group of 155 medical students, without prior experience of any kind of surgical simulators, executed five tasks (Peg board 2, Ring walk 2, Match Board 1, Ring and rail 2, and Thread the rings 2) on a virtual simulator for robot assisted surgery until reaching proficiency twice consecutively before moving to the next. A penalty was assigned each time a student was unable to complete a task or needed help from the tutor for successful execution. A weight was assigned to each task in terms of time and number of attempts to reach proficiency.

RESULTS
Nine students (5.8%) outperformed all the others on median (i.q.r.) weighted time (44.7 (42.2-47.3) min versus 98.5 (70.8-131.8) min, p<0.001), and number of attempts to reach proficiency (14 (12-15) versus 23 (19-32.75)), with significant difference (p<0.001), and without penalties in any task. Seventeen students (11.0%) scored much worse than the rest on median weighted time (202.2 (182.5-221.0) min versus 84.3 (65.7-114.4) min, p<0.001), and number of attempts (42 (40-48) versus 22 (17.25-28)), with significant difference, p<0.001, and receiving 14 penalties for Peg board 2, three for Ring walk 2, two for Match board 1, 18 for Ring and rail 2, and seven for Thread the rings 2. Low correlation between simulator scores and extra-curricular activities, like videogames and musical instruments, was found.

CONCLUSIONS
The test successfully identified proficiency gain curves of three distinct groups: gifted individuals, those with average, and those with scarce level of psychomotor skills. Hence, a test on a virtual surgical simulator can be considered as a part of the selection process of surgical residents.
LESSONS LEARNED AS A CREATOR & USER OF VR CONTENT FOR A SURGICAL SPECIALTY

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To overcome the shortcomings of the passive observation model of medical education, Simulation based educational tools were adopted by the Department of Ophthalmology, Loyola University Chicago. The goal was to create interactive educational opportunities based on sound educational principles. This led to the establishment of a Stereo learning center with innovative use of Virtual Reality simulation for accelerating knowledge and skills transfer. The center provides the Learner a safe environment for deliberate practice. It also serves as an opportunity for the Educator to observe, assess and give instant feedback to the Learner.

What was created for ophthalmology residents soon was in demand for training medical students, internal medicine residents and neurology residents. This led to a creative use of resources for larger numbers of students and for Learners with varying levels of training and with different levels of expertise requirements. Feedback from students was incorporated into subsequent sessions.

We would like to share the Lessons Learned through this experience for creation and adoption of Simulation based experiential training for any specialty.

A few photographs are included below:
SIMULATED SURGICAL ROBOT TRAINER FOR SURGICAL ASSISTANTS

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OBJECTIVE
Task performed by surgical assistants in a robotic operation requires training and rehearsal to accomplish task in a safe and efficient in an operating room (OR). Surgeons are extensively trained on the use of the robot console, but surgical assistants (such as scrub technician, circulating nurse, fellows, residents and medical student) are given limited training despite performing critical tasks, thus risking patient safety. In addition, setting up a robot prior to the operation requires special skill and team coordination. The time required to set up the robot prior to surgery is related to the performance of the OR team.

METHOD
We present a simulation trainer application for surgical assistants exploring both virtual reality (VR) and mixed reality (MR). Providing a limited hands-on training (limited due to expensive training process) will be insufficient as tasks performed by assistants vary between procedures, patients, and physician at the master console. The proposed simulation trainer aims to provide an interactive learning platform with potential to develop an extensive curriculum for practicing and knowledge acquisition. A detailed analysis of the learning components involved in the surgical robot training is identified and our approach to addressing those challenges is presented.

RESULT
The potentials of simulator trainer application are successfully demonstrated with the da Vinci™ surgical robot along with a real procedure called Nissen fundoplication. In addition to the interactive VR training (as shown in Figure 1), an Interactive Mixed reality 360-degree tutorial video is incorporated as part of training curriculum(as shown in Figure 2).

CONCLUSION
The significance of the presented simulator trainer demonstrated with the da Vinci surgical robot can be extended to other procedures and medical devices to provide a unique low-cost training.

KEYWORDS—Virtual reality, Mixed reality, Medical training, surgical robot training, Da Vinci surgical robot
ABSTRACT
Recent advances in robotic surgery have strained the limits of traditional surgical residency program directors (OB-GYN, GU and Gen Surgery) to provide adequate training in all routes of surgery: open surgery, minimally invasive (vaginal, laparoscopic and single port) and now robotic approaches are all being taught. Many residents report they feel unprepared to operate with proficiency in all areas after graduation. Simulation, either low fidelity or virtual has shown to be beneficial in helping students master psychomotor skills in various areas before using those skills for the first time, under supervision, on live surgical patients. An ideal training curriculum for VR simulation has yet to be determined.

METHOD
This study examines data from four different institutions that have used different approaches in employing virtual reality simulators to train surgeons to proficiency in operating the daVinci™ Surgical Robotic System. All learners utilized virtual robotic simulator exercises developed by Mimic Technologies, Seattle WA. Proficiency was defined at each institution as achieving consistent scores on exercises that demonstrated both surgical efficiency as well as avoidance of critical safety errors. The programs varied from labor intensive one week courses to one month courses fitted into normal training duties and finally courses spread out over an entire year for two institutions. Results evaluated were time to completion of enough critical exercises to demonstrate proficiency as well as the total numbers (percents) of students who achieved this goal.

RESULTS
Overall, residents and fellows accounted for > 70% of all student learners over all four programs with most being General Surgeons (59-88%) by specialty. The programs had significant variability in definitions of “becoming proficient.” The number of successful exercise completions to become “proficient” at each program varied quite a bit and amounted to 22, 39, 45, 54 & 102 exercises. The average time spent to become 100% proficient however ranged between 4.3 and 5 hours for all programs for those individual students who achieved “proficiency” by each program’s definition. The percentage of trainees who actually became proficient ranged from 0 at two programs that required consecutive passing scores to 70% for the program that required only one passing score as their definition. For the two programs that both required 2 consecutive passes with 3 or 5 total passes, the proficiency achievement was 31.7% for the program that required 45 passing exercise completions total over one year and 12.5% for the program that required 102 passing exercise completions total in one week.

CONCLUSIONS
The structure of these four programs reveals that there is no currently accepted best protocol available for training student surgeons to proficiency on the Intuitive Surgical daVinci™ robotic surgical platform. Having a simulator available does not insure that students will utilize it in the most effective way to achieve proficiency in operating a robotic surgical system. While all students benefited from practicing on simulation prior to trying to operate on animals or live patients, only a small percentage of students were able to achieve proficiency prior to starting to perform robotic surgery. This shortfall may be an indicator of innate ability in those who succeeded in becoming proficient or lack of adequate time to devote to simulation training in those who did not. The programs with more frequent and consistent simulation exposure tended to provide better results than a one-time intensive course or even a month long focused program. While attainment of proficiency was achieved at a higher rate with less stringent definitions of what that meant, a one-time successful completion of an exercise may not really indicate proficiency. This comparison can guide program directors to collaborate to develop a more reproducible and consistent training pathway for their robotic surgery students and may serve as a framework to design more effective simulation training studies in the future.
THE “VIRTUAL SKULL BASE LAB” – 3D ANIMATION AND VIRTUAL REALITY IN SURGICAL EDUCATION – THE NORTHWESTERN UNIVERSITY EXPERIENCE

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BACKGROUND
The traditional model of learning the complex neuroanatomy of the skull base requires not only extensive didactic learning, but also many hours of hands-on training through cadaveric dissections and operative cases. As access to cadavers becomes more expensive and limited, more operative cases are being managed non-operatively or with non-invasive techniques such as SRS, and trainee work hours are increasingly limited, there is a greater need for innovative models for surgical education. Recent developments in computer modelling, virtual/augmented reality, and video game technology have created new opportunities for novel teaching tools.

OBJECTIVES (OR AIM)
To develop a library of 3D models of normal anatomy and pathologic states for use in conjunction with an interactive simulated (virtual reality) environment for collaborative teaching of medical students, residents, and patients that can be used in the clinical setting, didactic teaching sessions, and as an adjunct to the skull base dissection lab.

METHODS
Anatomically accurate 3D models were developed using CT and MRI data from multiple patients using open source segmentation and 3D animation software. An interactive simulated environment was then created using a 3D game engine and used in conjunction with a virtual reality system.

RESULT
3D models and an interactive simulated environment were used in conjunction with various viewing modalities, including 3D video, 360 video, and virtual reality headsets. These teaching tools were successfully implemented in the neurosurgery clinic, didactic teaching sessions, and in the skull base lab.

CONCLUSION
3D modeling and animation show considerable promise for neurosurgical education as well as for patient engagement, marketing, and social media.

KEYWORD: 3D modeling, Virtual/Augmented Reality, Medical Education
SIMULATION-BASED LEARNING SYSTEM – THINKING BEYOND SIMULATION TO OPTIMIZE USER EXPERIENCE AND LEARNING OUTCOMES

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ABSTRACT

For several decades healthcare simulation has experienced tremendous interest, resulting in adoption in education and training. As part of this interest, surgical simulation has seen significant growth fueled by advancements in graphics visualization, physics modeling and haptics technology. The effectiveness of simulation depends on how well it is used. Despite this knowledge, a large number of products gather dust due to challenges in integration and use.

Research and experience in several other technology driven training interventions has revealed that the success of these solutions depends on the quality of the end user experience, which in turn influences their adoption, use and ultimate learning effectiveness.

Simulation fidelity does not have a direct relationship with learning effectiveness even though it can be correlated using validation studies. Given a certain level of task or procedural fidelity, it is the design and features of the Simulation-based Learning System (SBLS) that shape the learning experience and significantly influence the learning effectiveness.

HelpMeSee has developed a virtual reality eye surgery simulator for cataract surgery and a custom designed Simulation-based Learning System (SBLS) that is tightly integrated with simulation software.

The architecture and features of SBLS have been conceptualized to harness the power of simulation for training using a framework that takes into account various design discriminators. These address a wide range of pedagogical and application domain requirements. Some of these are difficult to freeze at the design stage and many features require flexibility that allows adaptation not just to training preferences but also to operational configurations at simulation training sites. These include use for instructor led training or independent practice, synchronous vs asynchronous sessions with instructors and multiple trainees, configurable learning paths, a library of scenarios that provide comprehensive coverage of learning objectives, management of scenario complexity, continuous user engagement with progressive increase in the difficulty levels, an assessment system with task and performance measures that can be evolved with learnings from validation studies and more. Simulation based training is not about replacing the live patient with a virtual one but rather it is an opportunity to transform the complete learning experience. The benefits can be tapped only with systematic design and requirements management, which have been present during the development of the HelpMeSee eye surgery simulator and associated standardized curriculum.

Thinking beyond simulation and associated fidelity to the design of Simulation-based Learning Systems (SBLS) has become imperative today for ensuring not just a good simulator but a comprehensive simulation-based training solution. Such design thinking and a complete solution, not just high-fidelity simulation, are critical for optimization of adoption, use and learning effectiveness from simulation-based training.

A simulation-based training effectiveness study of the HelpMeSee training solution has begun. Preliminary results will be ready for presentation at the conference.
INTRODUCTION
Laparoscopic skills training has traditionally relied on time metrics to demonstrate competency. Motion tracking during skills training allows for other objective measurements to differentiate between expert and novice surgeons. This project aims to identify if differences in the pathlength of laparoscopic tools during a simulated peg transfer task can serve to discriminate between individuals in different years of surgical residency, and be leveraged to develop a real-time feedback device capable of assessing laparoscopic skill proficiency.

METHODS
General Surgery residents (n=37) were asked to complete a peg transfer task on a custom designed laparoscopic simulator equipped with motion-tracking capabilities. Pathlength, measured by total path traced along the simulator’s x-axis, is defined as a sum of right and left laparoscopic tool values, accounting for dominant and non-dominant hand motion. Pathlength data was collected during task completion for each individual resident. Data were then assorted into three groups according to participant training experience. Group 1 consisted of PGY1 and PGY2 participants, Group 2 consisted of PGY3 and PGY4 participants, and Group 3 consisted of the most senior, PGY5 and PGY6 participants. Pathlength values were averaged group-wise to relate average pathlength with experience.

One-way ANOVA and Tukey’s post-test were used to compare mean pathlength between groups. Analyses were conducted using the SPSS statistical software package.

RESULTS
There were statistically significant differences in the mean pathlength between groups (p=0.05). Group 1 had a pathlength that was significantly longer when compared to Group 2 (215.61 +/- 54.61 vs 161.77 +/- 43.93, p<.05), and when compared to group 3 (215.61 +/- 54.61 vs. 161.05 +/- 49.65, p<.05). There was no significant difference between group 2 and 3 (161.77 +/- 43.93 vs. 161.05 +/- 49.65, p=.999). More specifically, the pathlength is longer for inexperienced residents relative to either of the more experienced groups.

CONCLUSION
This study revealed significant differences in the average pathlength of junior residents completing the peg-transfer task when compared to their more experienced peers. However, as the more experienced resident groups demonstrated similar average pathlengths, it is apparent that tool pathlength during the peg-transfer task plateaus between PGY2 and PGY6 and endures following proficiency attainment. Using this knowledge, it is feasible to suggest that pathlength can be pursued as a potential objective measurement of surgical skill proficiency, and employed for the future development of a real-time feedback device.
BACKGROUND

Fundamental Surgery is a first-of-its-kind SaaS software platform that combines virtual reality (VR) with cutting-edge haptics (the sense of touch) to create a low-cost and scalable flight simulator experience for trainee and qualified surgeons. Unlike other medical training simulations that make professionals feel like they have been through a game-like experience, Fundamental Surgery creates an authentic environment that allows users to experience and navigate the same visuals, sounds and feelings they would during a real surgical procedure.

Underlining the transformational potential of this technology, and validating the ground-breaking performance released by Fundamental Surgery, the Mayo Clinic (the U.S. leading academic medical center) has recently signed a three-year collaboration with FundamentalVR that will see the joint development of new training simulations and adoption of Fundamental Surgery throughout their network of surgical training simulation centres. We have also won TIME magazine top 50 inventions of 2018, and our system is implemented and being used in flagship teaching hospitals in London (Kings College London & UCLH).

We are living at a time when due to shortage of surgeons, 5 billion people globally are denied access to safe surgery due to a skills shortfall. Yet only 0.5% of surgical trainees have access to surgical simulation which has been proved to enhance skills acquisition and optimization. Fundamental Surgery gives healthcare professionals around the world low-cost access to authentic surgical simulations with precise measurement and performance insight.
SIMULATION-BASED PROCEDURAL SKILLS TRAINING FOR ADVANCED PRACTICE PROVIDERS

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DESCRIPTION OF PROBLEM/BACKGROUND
Advanced practice providers (APPs) fill an important role in seeing patients in many settings, particularly in outpatient clinics. Training for basic procedural skills in the outpatient setting is essential for APPs as they may be performing a wide range of procedural tasks. Didactic material in educational courses provides background knowledge, but does not provide the learner with an opportunity to practice and perform the specific skill. Simulation is beneficial for learners by giving them the opportunity to repeat skills for mastery, practice critical thinking skills, and be observed by faculty with opportunities for feedback and debriefing.

AIMS
This study describes a new advanced practice provider (APP)-led course designed to provide fellow APPs with formal training in basic procedural skills.

INTERVENTIONS
A needs assessment was performed and 13 skills were determined to be essential for APPs to master. Learners were given didactic material to review before attending the hands-on course consisting of PowerPoint slides as well as text book reference chapters. During the course, learners divided into instructor-led groups and rotated through 5 stations. Each station contained a hands-on simulation opportunity for practice of the skill as well as an opportunity for observation by the instructor with immediate feedback and debriefing.

MEASURES
After completion of a needs assessment, course curriculum and simulation models were developed. The curriculum was implemented and to date 22 learners have been trained. An 11-question pre and post-test was given and will be analyzed at the end of the academic year. Learners also recorded each skill they practiced during the course as an observed procedure.

RESULTS
A simulation-based skills training program for APP’s was successful implemented. Collecting pre and post-test data will assess learning provided from attending the course.

CONCLUSIONS
Based upon preliminary feedback from learners and facilitators, we anticipate an increase in skill confidence after participating in the course.