VIRTUAL MEETING

MARCH 10, 2021

SURGEONS AND ENGINEERS: A Dialogue on Surgical Simulation

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PROGRAM BOOK

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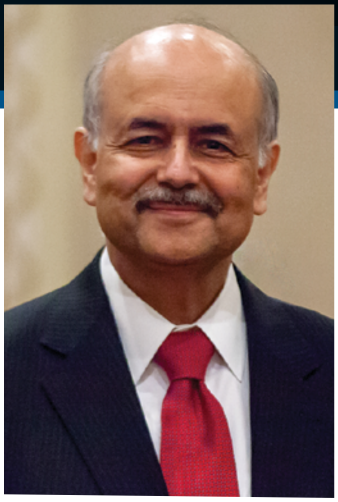


Welcome

On behalf of the American College of Surgeons (ACS) Division of Education, I would like to welcome you to the *2021 ACS Surgeons and Engineers: A Dialogue on Surgical Simulation* annual meeting. Given the success of the inaugural event in 2019, we have expanded the 2021 meeting to a full day. This will permit us to fully explore synergies between engineers, surgeons, scientists, physicians, and educators to advance simulation-based surgical education. In view of the COVID-19 pandemic, the 2021 meeting will be offered virtually.

Russell H. Taylor, PhD, John C. Malone Professor of Computer Science with joint appointments in mechanical engineering, radiology, and surgery, and Director of the Laboratory for Computational Sensing and Robotics, Johns Hopkins University, will deliver the Keynote Address. He has more than 40 years of professional experience in the fields of computer science, robotics, and computer-integrated interventional medicine. He is the recipient of numerous awards and is a recognized authority in computer-integrated interventional medicine, surgical robotics, medical image analysis, and human-machine cooperation in the operating room.

A Special Panel will follow the address and discuss various elements of successful collaboration between surgeons and engineers. The panelists include Robert Sweet, MD, FACS, Professor of Urology and Executive Director for the WWAMI Institute for Simulation in Healthcare (WISH) and the Center for Research in Education and Simulation Technology at the University of Washington; Gregory Hager, PhD, Mandell Bellmore Professor of Computer Science and Founding Director of the Johns Hopkins Malone Center for Engineering in Healthcare at Johns Hopkins University; Silvana Perretta, MD, Professor of Surgery and Chief of Foregut Surgery and Advanced Gastrointestinal Endoscopy Division, and Director of the Esophageal Motility Laboratory at the NHC University Hospital in Strasbourg, France; and Erik P. Dutson, MD, FACS, Clinical Professor of Surgery and Chief, UCLA Section of Minimally Invasive and Bariatric Surgery, and Executive Director of the Center for Advanced Surgical and Interventional Technology (CASIT) at the University of California, Los Angeles (UCLA).

The ACS Division of Education's Engineering Committee has selected 12 abstracts for podium presentations and 26 abstracts as scientific posters from the high-quality abstracts received. An interactive Breakout Session on topics encountered in surgeon-engineer partnerships will follow the presentations.

On behalf of the ACS Division of Education and the Division's Engineering Committee, thank you for attending this unique event. We look forward to continuing the productive dialogue we have initiated between surgeons and engineers aimed at fostering meaningful collaboration.

Ajit K. Sachdeva, MD, FACS, FRCSC, FSACME, MAMSE
Director, ACS Division of Education
Chair, ACS Program for Accreditation of Education Institutes

Program Objective

On behalf of the Program Committee and the Division of Education, welcome to the *Annual 2021 Virtual American College of Surgeons (ACS) Surgeons and Engineers: A Dialogue on Surgical Simulation.* In 2019, we received an overwhelming number of requests to expand this meeting, and we, therefore, hope you are as excited as we are to participate in a full day of activity!

The agenda for this meeting is specifically designed to help you appreciate a unique partnership of surgeons, academic and industry engineers, scientists, and surgical education leaders as well as enthusiastically contribute to this collaboration. By attending this meeting, it is our hope that you will gain a better understanding of the multifaceted needs, challenges, and potential benefits that arise from partnerships such as these that endeavor to support and promote the highest quality of surgical care through advanced knowledge and innovative education.

Through this collaboration, the Program Committee and the Division of Education have three essential goals: to bridge surgical and engineering communities, advance and support expertise and excellence in surgery, and enrich surgical simulation-based training with the most current dialogue on state-of-the-art technological and engineering advancements.

On behalf of the Program Committee, thank you for attending!

Gyusung Lee, PhD
Program Co-Chair
Assistant Director, Simulation-Based Surgical and Education Training, Division of Education, American College of Surgeons

Mandayam A. Srinivasan, PhD
Program Co-Chair
Founder, Laboratory for Human and Machine Haptics, Massachusetts Institute of Technology; Professor of Haptics, Computer Science Department, University College London, UK

With these goals in mind, the program committee has planned a premiere program to foster dialogue, enhance knowledge, build relationships, and spark ingenuity:

- **Keynote Address—Medical Robotics and Computer-Assisted Surgery:** Our keynote speaker, Russ Taylor, PhD, is a renowned authority on this subject with more than 40 years of professional experience in computer science, robotics, and computer-integrated interventional medicine.
- **Special Panel Discussion—Successful Collaboration between Surgeons and Engineers:** A special panel of surgeons and engineers, specifically chosen for their highly regarded expertise and experiences in surgeon-engineer partnerships, will share their knowledge and experience on this important topic.
- **Oral and Poster Presentations:** Our oral and poster presentations will shed light on the multifaceted collaborations between surgeons and engineers working together in research.
- **Breakout Session:** The interactive breakout session, which will include all meeting participants, is intended to address critical issues and challenges encountered in surgeon-engineer partnerships.

We are confident that you will find this meeting to be thought-provoking and rewarding, and we very much look forward to personally welcoming you at the post-meeting reception. Please provide us with your feedback to help ensure the success of this meeting at present and in the future.

Virtual Meeting Activities

All sessions will be held virtually for the meeting registrants in Central Time. The schedule is subject to change.

9:00–9:10 am	**Welcoming Remarks** Ajit K. Sachdeva, MD, FACS, FRCSC, FSACME, MAMSE, *Director, American College of Surgeons Division of Education* Gyusung Lee, PhD, *Program Co-Chair and Assistant Director, Simulation-Based Surgical Education and Training, American College of Surgeons Division of Education* Mandayam Srinivasan, PhD, *Program Co-Chair and Founder, Laboratory for Human and Machine Haptics, Massachusetts Institute of Technology; Professor of Haptics, Computer Science Department, University College, London, UK*
9:10–9:55 am	**Keynote Address** ***Medical Robotics and Computer-Assisted Surgery: A Three-Way Partnership between Physicians, Technology, and Information to Improve Patient Care*** Russell H. Taylor, PhD, *John C. Malone Professor of Computer Science with Joint Appointments in Mechanical Engineering, Radiology, and Surgery; Director, Laboratory for Computational Sensing and Robotics, Johns Hopkins University*
9:55–10:45 am	**Special Panel: *Surgeons and Engineers Successful Collaboration*** Robert Sweet, MD, FACS, *Executive Director of WISH, WWAMI Institute for Simulation in Healthcare; Medical Director, UW Medicine Kidney Stone Center; Professor, Department of Urology, University of Washington* Gregory D. Hager, PhD, *Mandell Bellmore Professor of Computer Science; Director, Malone Center for Engineering in Healthcare, Johns Hopkins University* Silvana Perretta, MD, *Professor of Surgery, University Hospital (NHC); Chief, Foregut and Advanced Gastrointestinal Endoscopy Division; Director of Education, IHU-Strasbourg; Vice-President, IRCAD, Research Institute Against Digestive Cancers, Strasbourg, France* Erik P. Dutson, MD, FACS, *Clinical Professor of Surgery, UCLA; Chief, UCLA Section of Minimally Invasive and Bariatric Surgery; Executive Director, Center for Advanced Surgical and Interventional Technology (CASIT), University of California, Los Angeles*
10:45–11:00 am	**Morning Break**
11:00 am–12:30 pm	**Oral Abstract Presentations** (full-text abstracts are provided on pages 10–16)
12:30–1:30 pm	**Scientific Poster Presentations** (full-text abstracts are provided on pages 18–31) **and Exhibitor Visits, Lunch Break**
1:30–1:45 pm	**Breakout Session Topics and Instructions** • Challenges in Writing a Multidisciplinary and Synergetic Grant Proposal • Overcoming Cultural Challenges between Surgeons and Engineers (including topics such as IP protection and whether a written collaboration agreement will help) • What Are the Top-Five Challenges in Technology-Enhanced Surgical Education?
1:45–2:45 pm	**Breakout Session**
2:45–3:15 pm	**Poster Visits and Afternoon Break**
3:15–3:50 pm	**Breakout Session Workgroup Reports**
3:50–4:00 pm	**Closing Remarks**
4:00–5:00 pm	**Independent Session: Advanced Modular Manikin (AMM)**
5:00–5:30 pm	**Welcome and Networking Reception** (open to all attendees)

**Please note: The virtual 2021 ACS Surgical Simulation Summit will take place on March 11–12.*

Program Chairs

Gyusung I. Lee, PhD

Assistant Director, Simulation-Based Surgical Education and Training, American College of Surgeons Division of Education

Gyusung Lee, PhD, is the Assistant Director of Simulation-Based Surgical Education and Training in the American College of Surgeons Division of Education. Dr. Lee obtained his training in academic laboratories as well as in clinical environments, performed sponsored research studies both independently and within teams, and championed the development and execution of various surgical education programs.

He completed his graduate studies in biomechanics and obtained MS and PhD degrees in the department of biomedical engineering at Texas A&M University in 1996 and 2002. Dr. Lee's dissertation research was an investigation of the mechanism of secondary injuries. After graduation, his post-doctoral training in the motor control laboratory at Arizona State University involved researching how joint coordination and control strategies are affected by the aging process and by Parkinson's disease. After two years of post-doctoral training, Dr. Lee joined the department of surgery at the University of Maryland School of Medicine (UMSOM) as a faculty research associate. His primary research interest at the UMSOM was to investigate the physical and cognitive ergonomics associated with various minimally invasive surgeries (MIS), including traditional laparoscopy, Natural Orifice Transluminal Endoscopic Surgery (NOTES), and robotic surgery.

Dr. Lee served as the director of Robotic Education and Ergonomics Research at the Minimally Invasive Surgical Training & Innovation Center (MISTIC) in the department of surgery at Johns Hopkins School of Medicine (JHSOM). One of his primary responsibilities in MISTIC was to develop the comprehensive robotic surgery training curriculum. This program provided surgical trainees with basic robotic skill training in preparation for the Fundamentals of Robotic Surgery (FRS), and advanced skill training for the immediate application of the learned skills in the trainees' actual case involvement. Using this curriculum, Dr. Lee offered robotic training to Hopkins residents, fellows, and attending surgeons from the specialties of general surgery, gynecology, surgical oncology, urology, and cardiac surgery. In addition, he also created a didactic and hands-on training program for operating room (OR) staff members assisting on robotic surgery cases. Through this program, Hopkins OR staff members receive skills training on a regular basis for establishing better teamwork between surgeons and OR staff members.

As the Assistant Director of Simulation-Based Surgical Education and Training, Dr. Lee provides leadership for a broad range of innovative simulation-based education and training programs of the Division of Education. He is responsible for designing simulation-based programs, providing leadership for the simulation research and development activities, especially those of the Consortium of ACS-Accredited Education Institutes, and building and strengthening collaborative relationships with national organizations and the federal government, including the Department of Defense.

Mandayam A. Srinivasan, PhD

Founder, Laboratory for Human and Machine Haptics, Massachusetts Institute of Technology; Professor of Haptics, Computer Science Department, University College, London, UK

Prof. Mandayam A. Srinivasan is the founder of the Laboratory for Human and Machine Haptics at the Massachusetts Institute of Technology and holds the professorial chair of haptics at the department of computer science, University College London, UK. He is also Vajra faculty at the Indian Institute of Technology Madras, India. He received a bachelor's degree in civil engineering from Bangalore University, a master's degree in aeronautical engineering from the Indian Institute of Science, and a PhD in mechanical engineering from Yale University. Following post-doctoral research at the department of anesthesiology, Yale University School of Medicine, he moved to MIT and founded the Laboratory for Human and Machine Haptics, known worldwide as the MIT Touch Lab.

Prof. Srinivasan's research over the past three decades on the science and technology underlying information acquisition and object manipulation through touch has played a pivotal role in establishing the multidisciplinary field of modern haptics. He has been recognized worldwide as an authority on computation, cognition, and communication through touch interactions in humans and modern machines such as computers and robots. His pioneering scientific investigations of human haptics involving biomechanics, neuroscience, and psychophysics has led to significant advances in our understanding of how nerve endings in the skin enable the brain to perceive the shape, texture, and softness of objects through the sense of touch. His work on machine and computer haptics involving design and development of novel robotic devices, mathematical algorithms, and real-time control software has enabled touching, feeling, and manipulating objects that exist only virtually as programs in the computer. He has also demonstrated novel haptic applications such as virtual reality-based simulators for medical training, real-time touch interactions between people across continents, and direct control of robots from brain neural signals. More recently, he has been working on developing haptic aids for blind people, smartphone-based health care for underserved populations, novel robotic fingertips, and teleoperation systems for micro/nano manipulation capable of performing surgery on a single cell with micron precision.

The international impact of Prof. Srinivasan's work has been multifaceted. He has led American and European multidisciplinary teams in a number of cutting-edge technology research projects. He has authored more than 230 publications in multiple fields ranging from neuroscience to robotics that include some of the most highly cited papers on haptics. He has given more than 130 invited talks all over the world, with many keynote or plenary talks in premier international conferences. A measure of wider societal impact is that Prof. Srinivasan has been featured or quoted in print media such as the Scientific American, Time, The Wall Street Journal, The New York Times, Times of India, Pravda, and Smithsonian, as well as by worldwide radio and TV networks such as BBC and CNN in programs focused on cutting-edge research in information technology and its future prospects. Several of the technologies that were developed in his lab have been displayed as hands-on interactive exhibits in many museums such as the Boston Museum of Science, MIT Museum, and V&A Museum in London.

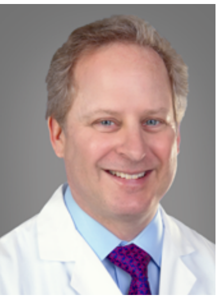
Keynote Speaker

Russell H. Taylor, PhD

John C. Malone Professor of Computer Science with Joint Appointments in Mechanical Engineering, Radiology, and Surgery; Director, Laboratory for Computational Sensing and Robotics, Johns Hopkins University

Russell H. Taylor received his PhD in computer science from Stanford in 1976. After spending 1976 to 1995 as a research staff member and research manager at IBM Research, he moved to Johns Hopkins University, where he is the John C. Malone Professor of Computer Science with joint appointments in mechanical engineering, radiology, and surgery and is also director of the Laboratory for Computational Sensing and Robotics (LCSR) and of the (graduated) NSF Engineering Research Center for Computer-Integrated Surgical Systems and Technology (CISST ERC). His research interests include medical robotics and computer-integrated interventional medicine. Dr. Taylor is a Fellow of the IEEE, the AIMBE, the MICCAI Society, the National Academy of Inventors, and the Engineering School of the University of Tokyo. He has received numerous awards, including the Maurice Mueller Award, the IEEE Robotics Pioneer Award, the IEEE EMBS Technical Field Award, and the Honda Prize. Dr. Taylor's research interests include all aspects of computer-integrated interventional medicine, with a special interest in surgical robotics, medical image analysis, and human-machine cooperation in the operating room.

Panelists



Erik P. Dutson, MD, FACS

Clinical Professor of Surgery, UCLA; Chief, UCLA Section of Minimally Invasive and Bariatric Surgery; Executive Director, Center for Advanced Surgical and Interventional Technology (CASIT), University of California, Los Angeles

Dr. Erik Dutson is a professor of surgery at UCLA and is the chief of minimally invasive and bariatric surgery. Dr. Dutson is currently the executive director of UCLA's Center for Advanced Surgical and Interventional Technology (CASIT), a lab focused on collaboration between physicians and engineers to create advanced tech and to train clinicians on the latest technologies. Dr. Dutson has been on faculty at UCLA since 2003 and played a minor ancillary role in Operation Lindbergh, a transatlantic telerobotic cholecystectomy performed by Jacques Marescaux in 2001.

Gregory D. Hager, PhD

Mandell Bellmore Professor of Computer Science; Director, Malone Center for Engineering in Healthcare, Johns Hopkins University

Gregory D. Hager is the Mandell Bellmore Professor of Computer Science at Johns Hopkins University and founding director of the Malone Center for Engineering in Healthcare. Professor Hager's research interests include collaborative and vision-based robotics, time-series analysis of image data, and medical applications of image analysis and robotics. He is past Chair of the Computing Community Consortium, a member of the governing board of the International Federation of Robotics Research, and a member of the CISE Advisory Committee. Professor Hager has served on the editorial boards of IEEE TRO, IEEE PAMI, and IJCV. Professor Hager is a fellow of the ACM, IEEE, and AAAS for his contributions to vision-based robotics and a Fellow of the MICCAI Society and of AIMBE for his contributions to imaging and his work on the analysis of surgical technical skill. Professor Hager is a co-founder of Clear Guide Medical and of Ready Robotics.

Silvana Perretta, MD

Professor of Surgery, University Hospital (NHC), Strasbourg, France; Chief, Foregut and Advanced Gastrointestinal Endoscopy Division; Director of Education, IHU-Strasbourg, France; Vice-President IRCAD, Research Institute Against Digestive Cancers, Strasbourg, France

Dr. Silvana Perretta is an upper gastro-intestinal surgeon, chief of foregut and advanced gastrointestinal endoscopy division. Dr. Perretta has served as director of IHU Education and of the surgical endoscopy fellowship program since 2014. Since 2011, Dr. Perretta has run the Business Engineering and Surgical Technologies (B.E.S.T) education program, a custom-designed health care innovation program. Her fields of interest include upper gastro-intestinal surgery, gastro-intestinal physiology, bariatric surgery, interventional endoscopy, surgical education, and innovation. Dr. Perretta has been a pioneer in the development of Natural Orifice Transluminal Endoscopic Surgery (NOTES), hybrid surgical endoscopy procedures, endoscopic platforms, flexible robotics, image-guided therapies, endoscopic simulators, and MOOC-oriented medical education worldwide.

In 2011, Dr. Perretta was awarded the SAGES career development award. Dr. Perretta recently received a €1.2 million government research grant for the development of e-learning and education in the field of surgical endoscopy, image-guided therapy, and med-tech innovation, and a €140 thousand grant from the University of Strasbourg's Institute for Advanced Studies to develop hybrid materials for fighting obesity. She has been the vice-president of IRCAD France since June 2019.

Robert Sweet, MD, FACS

Executive Director of WISH, WWAMI Institute for Simulation in Healthcare; Medical Director, UW Medicine Kidney Stone Center; Professor, Department of Urology, University of Washington

Dr. Sweet is a professor of urology, surgery, and bioengineering at the University of Washington and the founding medical director of the UW Medicine Kidney Stone Center. Dr. Sweet founded and led the University of Minnesota's SimPORTAL and cofounded the University of Washington's ISIS, which was renamed the University of Washington, Wyoming, Alaska, Montana, and Idaho Institute for Simulation Technologies (WISH) when he assumed the executive director position. He is the Principal Investigator (PI) for all programs in the Center for Research in Education and Simulation Technologies (CREST), including the "Advanced Modular Manikin" project. CREST programs have been funded by the Department of Defense, NIH, and industry and have led to the development of numerous health care simulation training devices and curricula. Effective January 1, 2020, a Division of Healthcare Simulation Sciences, uniting WISH, CREST, and health care simulation academic programs under a formal academic unit, was established at the University of Washington with Dr. Sweet now serving as the founding division head.

Dr. Sweet is an "Arthur Smith Award" winner and is the PI of numerous simulation research and development projects. Seattle Business Magazine awarded him and his programs the 2019 "Leaders in Health Care, Achievement in Medical Technology" Gold Award.

Dr. Sweet has served in leadership positions in simulation and education within the American College of Surgeons, the Society of Laparoendoscopic Surgeons, the Endourology Society, and the American Urological Association. Dr. Sweet helped develop the Surgical Simulation Fellowship Accreditation Program for the American College of Surgeons Division of Education and started two such programs at the Universities of Minnesota and Washington. He is most proud of the accomplishments of his graduating fellows.

For his contributions to surgical education, Dr. Sweet was inducted as a Member of the American College of Surgeons Academy of Master Surgeon Educators™ inaugural class in October 2018, and he was the recipient of the 2019 American Urological Association Distinguished Contribution Award.

Abstract Code Abstract Category

O-1 Research In-Progress

Machine Learning and Mixed Reality Surgical Simulator for Autonomous Instructional Guidance and Performance Assessment

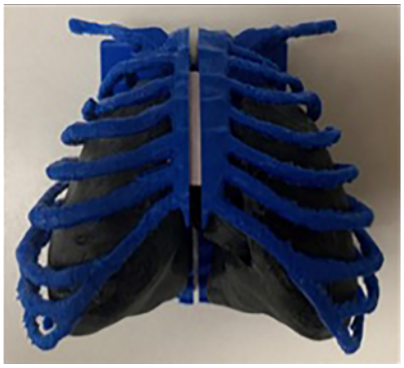
Nihar N. Sheth, MS, Mechanical Engineering; Nicholas Marjanovic, BS, Bioengineering; Nishant Srinivasan, MBBS, MD, Pediatrics, Neonatal-Perinatal Medicine; Cristian J. Luciano, PhD, MS; and Saurabhkumar C. Patel, MD, MPH, Pediatrics and Neonatal-Perinatal Medicine
University of Illinois at Chicago, Chicago, IL

Introduction: Interactive instructional feedback and performance assessment of learners during surgical simulation and training are effective to increase patient safety, but they are long, subjective, difficult, expensive, and instructor-heavy tasks. The goal of this project is to develop a fully autonomous training system that will be able to provide precise, accurate, and real-time instructional coaching, as well as objectively measure learners' skill performance using a combination of machine learning (ML) and mixed reality (MR) technologies. As a proof of concept, the simulator will be applied for teaching neonate thoracentesis and pericardiocentesis, which are rare but complex life-threatening procedures.

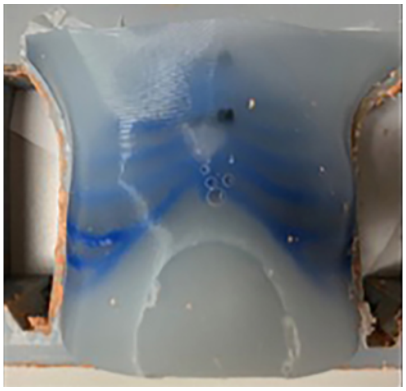
Methods: Based on MRI and CT scans of real patients, a virtual 3D anatomical model has been designed and used to create a manikin using 3D printing technology. The flexible organs (pleura, collapsed lung, and heart) and rigid bony structures (ribcage and spine), have been encased in flexible silicone to simulate the skin and underlying soft tissue. A software application is currently being developed for combing real and virtual 3D patient anatomy and surgical instruments in a mixed reality environment. Trainees' actions during surgical training are determined by tracking and storing the 3D positions and orientations of multiple surgical instruments with an NDI DriveBay electromagnetic system.

Preliminary Results: The flexible 3D printed organs allow for realistic ultrasound-assisted needle insertion. A preliminary evaluation and content validation about anatomical details, realism of ultrasound guidance, and tactile feedback have been provided by Pediatrics surgeons, experts in performing and teaching these surgical procedures.

Next Steps: The captured tracking motion data will be used to train a recursive neural network to detect and classify the execution of the different surgical steps being performed by experts and novices during the simulated surgical procedures, and in-turn provide relevant instructional guidance and valuable feedback about the trainees' surgical skills.



3D-printed model of flexible lungs and pleura and rigid ribcage.



Flexible silicone enclosing the 3D-printed neonate anatomy.

O-2 Research

Open Source Platform for Automated Collection and Interpretation of Training Data in Open Surgery

Jacob R. Laframboise; Tamas Ungi, MD, PhD; Kyle Sunderland, MSc; Gabor T. Fichtinger, PhD; and Boris Zevin, MD, PhD, FACS
Laboratory for Percutaneous Surgery, Queen's University, Kingston, ON; Department of Surgery, Queen's University, Kingston, ON

Introduction: Automatic detection of workflow steps in surgery could improve surgical training. Additionally, automatic surgical video annotation could generate useful surgical training material. A platform to collect and organize tracked video data would enable rapid development of deep learning solutions for surgical video annotation in open surgery. The purpose of this research was to demonstrate surgical video annotation on the 3D Slicer / PLUS Toolkit platform by classifying and annotating tissue-tool interactions in simulated open inguinal hernia repair.

Methods: PLUS Toolkit collected tracking data from an optical tracker and video data from a camera, which were saved in 3D Slicer. To demonstrate the platform, we identified tissues being interacted with in surgical video using a neural network and identified the tool in use with the tracking data. A custom Slicer module was used to deploy this model for real-time annotation.

Results: This platform allowed the collection and organization of over 120,000 labelled tracked video frames for training a convolutional neural network (CNN) to detect tool interactions with tissues. The CNN was trained on this data and applied to new data with a testing accuracy of 86%. The model's predictions can be weighted over several frames with a custom Slicer module to improve accuracy.

Conclusions: Our proof of concept model successfully identified tissues with a trained CNN in real time (30fps), while optical tracking data identified the tool. The 3D Slicer and PLUS Toolkit platform is a viable platform for rapidly collecting a large volume of training data in short time. The platform allows deployment of a solution utilizing optical tracking and video processing for real-time annotation (Figure). This motivates further use of 3D Slicer / PLUS in video annotation and training in open surgery.

O-3 Promoting Technology and Collaboration

Retropubic Trocar Modified with a Load Cell to Measure Force

Gary Sutkin, MD; Gregory W. King, PhD; and Antonis P. Stylianou, PhD
University of Missouri, Kansas City, Kansas City, MO

Background: The Midurethral Sling surgery involves blind passage of a sharp steel trocar within millimeters of the urethra and bladder, and 2-5 centimeters from the bowel and iliac and obturator vessels: injuries are well documented. Safe procedures involve maintaining constant trocar contact with the suprapubic bone, which can be difficult for a teaching surgeon to assess when a resident performs.

Technology Overview: This force-sensing trocar was developed through collaboration between a pelvic surgeon and two biomedical engineers. We modified a retropubic TVT trocar (Ethicon, 810041BL) with a load cell (Futek LCM200) retaining the original dimensions and recording unidirectional force exerted on its handle.

Potential Application in Surgical Simulation and Education: Two pelvic surgeons performed bilateral retropubic passage of the force-sensing trocar on a thiel-embalmed cadaver and a physical model on two different occasions. The physical model was created by segmenting a Midurethral Sling candidate's MRI, 3D-printing, and filling with thermoballistic gel. Cross-correlation analyses on time- and amplitude-normalized force time histories revealed high correlations between model forces measured on different occasions; and between model and cadaver forces. Paired t-tests on maximal amplitude (F_{max}) and root-mean-squared amplitude (F_{rms}) from force time histories revealed no significant differences between model trials on different occasions (F_{max}: p=0.786 and p=0.253 for right and left passages, respectively; F_{rms}: p=0.327 and p=.277 for right and left passages, respectively); and few significant differences between model and cadaver trials (F_{max}: p=0.036 and p=0.286 for right and left passages, respectively; F_{rms}: p=0.053 and p=.101 for right and left passages, respectively). This suggests high test-retest reliability of the model/trocar system, and adequate biofidelity of the simulation model.

Potential Opportunities to Collaborate: In our next collaboration, this novel force-sensing trocar will be used to test the role of force in injury to vital organs. Expert surgeons and PGY1-4 residents will perform retropubic trocar passage on the simulation model using the force-sensing trocar. Unidirectional force will be supplemented with motion capture data, recording contact between the tip of the trocar and bone.

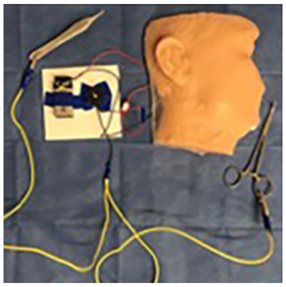
O-4 Research In-Progress

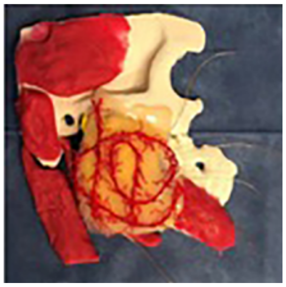
The Development and Validation of a Novel High-Fidelity Simulator for Parotid and Facial Nerve Surgery

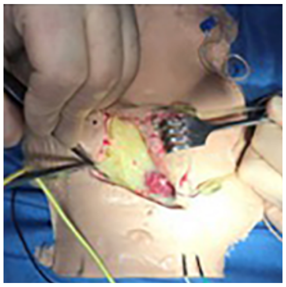
Fanny Gabrysz-Forget, MD, and Bharat Bhushan Yarlagadda, MD, FACS
Lahey Hospital and Medical Center, Burlington, MA

Introduction: Parotid surgery is challenging to learn and teach due to potentially morbid complications such as facial nerve injury. We present the development of a novel low-cost high-fidelity model for training of parotidectomy with pilot data of prospective validation studies.

Methods: The model consists of a 3D-printed skeletal and multiple silicone-based soft tissue portions of various densities to replicate skin, parotid, and tumor. Copper wire replicates the facial nerve and is circuited to indicate contact with instruments. Face validity is evaluated using a 21-item 5-point Likert scale QR. Participant performance was likewise evaluated. Content validity was determined by comparing expert and novice performance, and via a survey completed by the trainees after their immediate subsequent live parotidectomy following simulation.







Preliminary Results: Twelve residents and six faculty completed the simulated procedure of superficial parotidectomy after watching a video demonstration. Over the 16 steps of the surgery evaluated by this simulator, the mean assessment score for faculty was 15.83 ±0.41 compared to 13.33±2.06 for residents (p=0.0081). The ability to distinguish groups indicates high content validity. Overall, the value of the simulator as a training tool was well received by both faculty and residents (5 vs 4, p=0.0206), however faculty were more likely to respond positively with regards to overall realism (4.5 vs. 3.5, p = 0.0155), and tumor realism (5 vs 4, p = 0.0264). Low scores were received particularly regarding skin realism.

Next Steps: This low-cost soft-tissue surgical trainer for parotidectomy and facial nerve dissection has showed face and content validity and will contribute the surgical education of early stage trainees. As low feedback was received regarding skin tissue realism and quality, future directives are intended to improve the soft tissue quality via alteration of the silicone materials used. In addition, sensors can be used in the circuit to indicate duration and intensity of facial nerve contact, rather than the current binary feedback. Similar models can be applied to additional anatomies, such as thyroid surgery.

O-5 Research

Non-Inferiority Assessment of a Self-Study; Self-Debriefing Mixed Reality Simulator for Central Venous Access

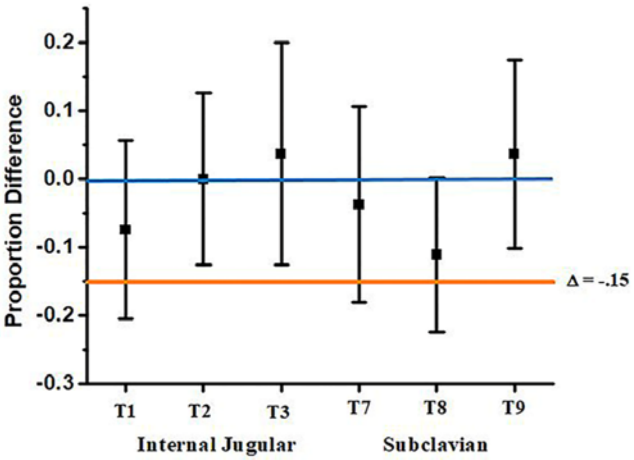
Samsun Lampotang, PhD, FSSH; George Sarosi, MD; Edward McGough, MD; Nikolaus Gravenstein, MD; Lou Ann Cooper, PhD; David Lizdas, BS; Anthony DeStephens, MSME; Andrew Gifford, BS; Desmond Zeng, MS; and Josh Sappenfield, MD
University of Florida, Gainesville, FL

Introduction: Simulators are more often idle than not. We developed a simulator with an optional integrated tutor (IT) for self-study/self-debriefing when instructors are unavailable. We hypothesize that our IT has similar, rather than superior, effects, i.e., can be non-inferior to an Anesthesiology human instructor (HUM) in helping trainees acquire procedural skills on a simulator.

Methods: We conducted a power analysis/sample size calculation for a non-inferiority analysis on the difference in two independent proportions, assuming α=0.05, power=0.80, a high success rate expected for both groups (95%) and a non-inferiority margin of 15%. We assessed 54 randomly assigned trainees (IT=27; HUM=27) on central venous access (CVA) performance via both internal jugular (IJ) and subclavian (SC) approaches. We assessed baseline performance for ultrasound (US)-guided IJ access and landmark-based infraclavicular SC access. Participants were taught both methods of obtaining CVA on the same simulator by the IT or HUM. After instruction, we evaluated participants on 3 trials per approach. US-guided short and long axis techniques were required for IJ. Competency was defined as obtaining central venous access in 3 consecutive attempts without pneumothorax or arterial puncture. The non-inferiority analysis (Farrington-Manning test, SAS 9.4) for the proportion difference assumed a non-inferiority margin of 15% (H0: IT-HUM ≤ −0.15 vs. Ha: IT-HUM > −0.15). All trials were of normal anatomical difficulty.

Results: Because the non-inferiority margin, −0.15, does not fall within the confidence interval, we conclude that IT is non-inferior to HUM for trials 2, 3, and 9 (Table).

Conclusions: Having established non-inferiority, we then used the simulator, together with its IT, to train 198 surgery, anesthesiology, EM residents; CCM, Neurology fellows; and SICU APPs to competency in US-guided IJ CVA (May-August 2018) as part of an ongoing patient outcome study. An integrated tutor makes simulation-based training more accessible when instructors are unavailable.



Trial	Approach	Success IT	Success HUM	Difference	Fisher's Exact p-value
1	IJ, long axis	88.89	96.30	-0.0741	0.61
2	IJ, short axis	96.30	96.30	0.0000	1.00
3	IJ, long axis	88.89	85.19	0.0370	1.00
7	SC	88.89	92.59	-0.0370	1.00
8	SC	88.89	100.00	-0.1111	0.24
9	SC	96.30	92.59	0.0370	1.00

O-6 Research

Segment-Level Assessment of Surgical Technical Skill Using Machine Learning for Automated Surgical Coaching and Deliberate Practice

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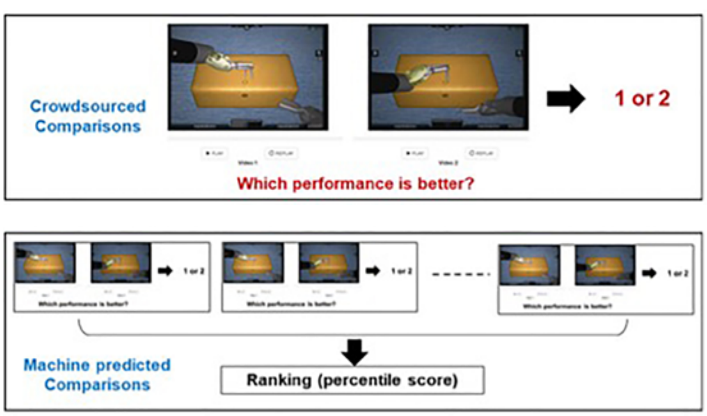
Introduction: Technical skills coaching is important for improving patient outcomes in surgery. However, expert one-on-one coaching is not scalable for routine assessment and feedback. Our work is toward augmenting a human surgical coach with an automated virtual coach. Routine and targeted assessment is needed to enable deliberate practice which leads to efficient and effective learning. In this work, we present an approach that can generate ranking scores for a given performance at segment-level.

Methods: We used a dataset of 30 performances of the "Suture Sponge I" task available on the da Vinci Skills Simulator, a virtual reality simulation training platform for the da Vinci system. This dataset contained video, instrument motion, and endoscope motion recordings. We labeled start and end of each constituent needle passing segment resulting in 360 such segments. We obtained pairwise comparisons-based skill ratings for 100 pairs of performances generated by random selection of segments. This involved a rater to view a pair of performances side-by-side on a web page and select their "preference" indicating the better skilled performance. The rater indicated their level of confidence in choosing the preference on a 3-choice question. We recruited 5 raters per pair and chose the majority rating as the preference for the pair. We computed 7 metrics using motion data, e.g., completion time, instrument path length, instrument shaft area swept, and instrument velocity peaks. We used the "support vector machine" algorithm, a machine learning technique, to predict preferences by using the metrics for the given pair of performances. We performed 5-fold cross validation to estimate the accuracy of the algorithm.



Segment-level assessment using pairwise comparisons-based ranking. The percentile rank scores provide targeted feedback to the learner on which segment to focus on, enabling deliberate practice.

Results: The inter-rater agreement in preference ratings was moderate (Fleiss kappa of 0.51, percent agreement of 85.5%). The support vector machine algorithm predicted preferences with 85.48% accuracy (standard error: 0.35).

Conclusions: A support vector machine algorithm can predict pairwise comparisons of needle passing segments with accuracy that is similar to the inter-rater agreement within human ratings of such comparisons.

O-7 Research

LapTool-Net™: A Context-Aware Deep Learning System for Automatic Detection of Surgical Tools in Laparoscopic Videos

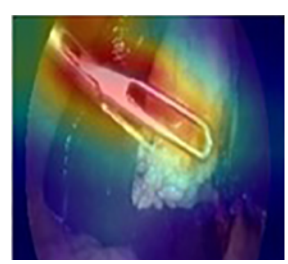
Babak Namazi, PhD; Ganesh Sankaranarayanan, PhD; and Venkat Devarajan, PhD
University of Texas at Arlington, Arlington, TX; Baylor University Medical Center, Dallas, TX

Introduction: Monitoring the usage of different surgical instruments in a laparoscopic procedure is a critical part of developing an automated system for tracking surgical actions. The objective of our technology is to develop the LapTool-Net™, a deep learning-based system for automatic detection of surgical tools.

Methods: LapTool-Net is a multi-label classifier that was designed to detect the presence of surgical tools in a laparoscopic video. It is a deep CNN-RNN model, where CNN is a deep feed-forward artificial neural network that is trained to learn high-level features in still frames of the video, and RNN is trained using a sequence of frames from the videos to learn the temporal features. The unique aspect of the LapTool-Net is the awareness of the context of the usage of the surgical tools, i.e., the tools' co-occurrence pattern, and the correlation between the tools and the tasks.

Results: We used the publicly available cholec80 dataset, which contains 80 videos of laparoscopic cholecystectomy. The extracted frames were manually labeled for seven tools; bipolar, clipper, grasper, hook, irrigator, shears, and specimen bag. The training set contained 40 videos that were used to train the CNN-RNN model based on an inception-V1 and Gated Recurrent Unit (GRU) architectures. The other 40 videos were used for validating the performance of the model. Our current accuracy is 85.77% for online mode and 91.92% for offline mode. The average per-class F1-scores are 93.10% and 96.11% for online and offline respectively. The processing time for each frame is <0.01 seconds, which makes LapTool-Net suitable for real-time applications.

Input frame for Grasper



Correct prediction for Grasper

Conclusions: LapTool-Net can be used in real-time for monitoring surgical actions to prevent errors and provide instantaneous feedback for quality improvement. It can also be used offline for the assessment of the recorded videos, information retrieval for education purposes and operative summary report generation.

O-8 Research In-Progress

Interprofessional Discovery Learning of the Human Biomedical Musculoskeletal System: Combining a Virtual Patient Case and a Finite Element-Based Cervical Spine Model to Visualize Trauma Biomechanics

Li Fellander-Tsai, MD, PhD
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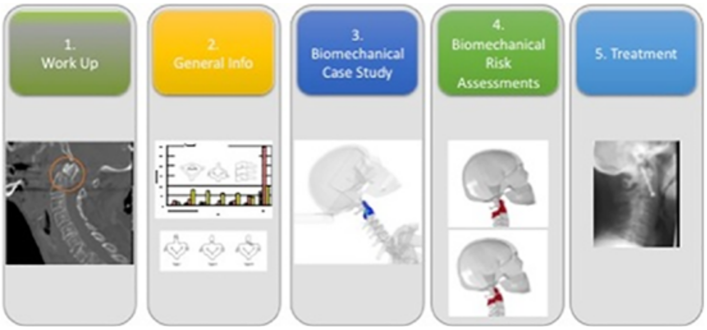
Introduction: This project focuses on knowledge generation and integration in a virtual environment combining a virtual patient case and a finite element model (FEM) based cervical spine injury. Special focus is on interprofessional learning in medical-, nursing, physiotherapy- and occupational therapy students. New visualization techniques and virtual environments enable design of educational arrangements directed toward competencies that cannot be learnt by traditional forms of university-based education. Understanding human anatomy can be identified as memorizing, contextualizing and experiencing. Today, normal and pathological anatomy can be visualized by e.g., Computed Tomography (CT) and Magnetic Resonance Imaging (MRI). Visualization of different diagnoses for clinical application and treatment is a significantly expanding area within health care. For instance, so-called *passive visualization* includes CT and MRI, and is mainly used for the visualization of anatomical and functional structures. However, so-called *active visualization*, including haptic devices in virtual reality, is just in its infancy.

Methods: A PC based virtual program combining a virtual patient case with a cervical spine fracture and FEM visualizing the biomechanics of the fracture was developed (Figure). Ten interprofessional groups of three students enrolled in different programs, (medical-, nursing and physiotherapy-/occupational therapy students) were video recorded while going through the virtual program. Student interactions were analyzed as well as interactions with the visualization program. Focus group interviews were undertaken. The study was approved by the regional ethical committee (Dnr 2016/450-31).

Preliminary Results: The focus group interviews revealed that students in general appreciate learning with the visualization program. Analyses of the video recordings regarding interactions between the students as they work their way through the visualization program indicate that the format stimulates embodied understandings of the biomechanical conditions related to the case. The findings indicate that the visualization program induces interprofessional clinical reasoning among the students.

Next Steps: Active visualization of biomechanical events in trauma holds promise for interprofessional training. Analysis of the variation in how interprofessional collaboration emerges as an effect of the interaction with the visualization program is ongoing.



O-9 Research In-Progress

Universal Segment Connector for the Advanced Modular Manikin

David M. Hananel, BSEE, BACS, and Robert Sweet, MD, FACS
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Introduction: Simulation has gained wide acceptance within the health care education community to supplement and in certain cases replace the traditional training methods on patients. The DoD has funded a series of landmark programs to create Open Source health care simulation tools, such as a physiology engine, BioGears and the Advanced Modular Manikin (AMM). The AMM solicitation stipulated a modular, distributed, interoperable platform that could be expanded from the very simple trainers for first responders to very complex trainers for surgical sub-specialties. To accomplish this, we established open standards for interoperability. A critical component of the open standards is a Universal Segment Connector (USC) that must be used between the segments for them to connect and work as an integrated system.

Methods: The development team carefully reviewed competing requirements for the segment connectors. The competing requirements were discussed and evaluated by clinicians, design engineers, manufacturing engineers and simulation technicians to reach consensus on design specifications. The development team considered over twenty alternatives during both phases of the program, tested the most promising ones for performance.

Preliminary Results: The design requirements considered many competing items, such as strength, weight, cost. These were weighed against operational requirements of power, data and fluidics throughput. The design iterations were focused on the balance between performance and cost, engineering creativity allowed us to reduce cost by an order of magnitude without sacrificing performance. The following table documents the test results from the project.

Next Steps: The final design was provided to two vendors for low volume production and provides the physical connection, power and data, as well as compressed air and multiple fluid lines at each segment interface. The Universal Segment Connector for the AMM platform is now available to developers through the AMM web site. It is now ready for potential developers to adopt.

Test Performed	Sub-Test	Connector	Test Spec.	Pass/Fall
Axial Load	Mechanical	Entropic	300 lbs.	Pass
		2nd Party	300 lbs.	Pass
		Hybrid	300 lbs.	Pass
	Electrical	Entropic	200 lbs.	Pass
		2nd Party	200 lbs.	Pass
		Hybrid	200 lbs.	Pass
	Fluid	Entropic	200 lbs.	Pass
		2nd Party	200 lbs.	Pass
		Hybrid	200 lbs.	Pass
Bending	Mechanical	Entropic	100 ft-lbs.	Pass
		2nd Party	100 ft-lbs.	Pass
		Hybrid	100 ft-lbs.	Pass
	Electrical	Entropic	100 ft-lbs.	Pass
		2nd Party	100 ft-lbs.	Pass
		Hybrid	100 ft-lbs.	Pass
	Fluid	Entropic	100 ft-lbs.	Pass
		2nd Party	100 ft-lbs.	Pass
		Hybrid	100 ft-lbs.	Pass
Vibration	Mechanical	Entropic	10 Hz–1.5 kHz	Pass
		2nd Party	10 Hz–1.5 kHz	Fail*
		Hybrid	10 Hz–1.5 kHz	Pass
	Electrical	Entropic	10 Hz–1.5 kHz	Pass
		2nd Party	10 Hz–1.5 kHz	Pass
		Hybrid	10 Hz–1.5 kHz	Pass
	Fluid	Entropic	10 Hz–1.5 kHz	Pass
		2nd Party	10 Hz–1.5 kHz	Pass
		Hybrid	10 Hz–1.5 kHz	Pass

*This was considered a **failed** test because, during the vertical orientation test, one of the internal screws became unscrewed and fell out of the back of the connector (see figure). The proposed steps necessary to prevent this mode of failure in future connectors is to ensure that Loctite is used when mounting all screws in the connector.

O-10 Research In-Progress

Development of an Ergonomic Model to Assess Musculoskeletal Risks in Minimally Invasive Surgery

Dimitrios I. Athanasiadis, MD; Sara Monfared, MD; Hamed I. Asadi, MS; Denny Yu, PhD; and Dimitrios Stefanidis, MD, PhD
Indiana University School of Medicine, Indianapolis, IN; Purdue University, West Lafayette, IN

Introduction: Work-related musculoskeletal injuries among minimally invasive surgeons are alarmingly high due to technically demanding and static postures. The primary outcome was to assess the ergonomic demands of MIS surgeons and trainees. Secondary outcome was to assess the relationship between ergonomic objective and subjective measurements.

Methods: An IRB-approved prospective study was conducted between July and February 2019. Ergonomic data was obtained during minimally invasive procedures from 6 surgical attendings and 6 residents and fellows using subjective tools (Musculoskeletal Symptoms Response questionnaire and the National Aeronautics and Space Administration Task Load Index) and objective metrics (electromyography [EMG] activity and inertial measurement unit recordings). Statistical analysis was performed to determine the relationship between objective and subjective measurements.

Preliminary Results: A total of 57 case observations were performed (45 laparoscopic and 12 robotic procedures). The average percentage of time that the participant spent in trunk static position was 67% and neck static position was 52%, while the average percentage of time spent in trunk demanding position was 11% and neck demanding position was 38%. 51% of participants reported neck stiffness after surgery which was significantly associated with a higher percentage of time in static position of the trunk (70% vs 62%, p=0.01) and neck (56% vs 48%, p=0.01). The table shows the correlations between perceived effort and EMG activity. Both attendings and trainees spent similar time in demanding and static positions of the trunk, neck, right and left shoulder and their perceived effort did not differ significantly.

Next Steps: We observed high static positioning with low weight shifting during MIS procedures that increase the ergonomic strain on the body. These findings can be used as biomechanical engineering markers to develop a musculoskeletal risk predictor model and assess the impact of interventions such as exoskeleton devices in alleviating ergonomic risk.

Table. EMG activity correlated to perceived physical effort.

Perceived Effort Right Trapezius	**Left Trapezius**	**Left Deltoid**	**Left Deltoid**
Neck	0.426 (p<0.01)	0.25 (p=0.079)	0.25 (p=0.079)
Back	0.289 (p<0.05)	0.272 (p=0.056)	0.272 (p=0.056)
Right Arm	-0.024 (p=0.868)	0.005 (p=0.975)	0.005 (p=0.975)
Left Arm	0.041 (p=0.779)	0.243 (p=0.089)	0.243 (p=0.089)
Overall physical Demand	0.472 (p<0.001)	0.310 (p<0.05)	0.310 (p<0.05)

O-11 Research In-Progress

Review of the Range and Makeup of Simulators for Upper and Lower Limb Exploration Surgery

Leonie Heskin, Ciaran Simms, and Rose Galvin
RCSI, Dublin, Ireland; TCD, Dublin, Ireland; UL, Limerick, Ireland

Introduction: Surgical training has undergone a paradigm shift where the traditional 'master-apprentice' model has been replaced with an increased focus on competency-based education. Simulation training provides a means for surgical trainees to practice technical tasks in a protected environment without putting patients at risk and it enhances the learning experience. This review aims to explore the totality of evidence with regard to the types of and make up of both full and part-task trainers to teach surgeons extremity exploration procedures.

Methods: A comprehensive literature review was performed according to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) statement. The data bases searched were PubMed, Web of Science, CINAHL and Embase. Studies were included if they reported the development and/or validation of synthetic or virtual task trainers. Studies were evaluated against a reference standard set of 14 criteria derived from existing literature to determine their derivation, usability and clinical utility.

Preliminary Results: A total of 583 citations were identified and 62 satisfied the inclusion criteria. Nine were full and 51 part-task trainers. Twenty-four papers addressed simulator validation and 36 addressed level of learning achieved with the use of the simulator. Two studies described a dedicated limb simulator. Simulators were developed to repair limb structures including Skin (n=15), Tendon (n=7), Nerve (n=1), Fascia (n=1), Muscle (n=1), Vascular (n=24), bone (n=10). All simulators composition varied using materials such as silicone, latex, rubber micro foam, ethylene-vinyl-acetate, polyvinyl alcohol (PVA) hydrogel, polytetrafluoroethylene (PTFE) and polyethylene.

Next Steps: There was no consensus across the studies on the optimal material makeup of the simulators used to teach the repair of structures in limb exploration surgery. The full limb simulators described were both virtual reality simulators. The next steps are to explore the features of amalgamating the findings for construction of a full synthetic limb simulator.

O-12 Promoting Technology and Collaboration

Digital Transformation of Surgery In and Out of the Operating Room

Petros Giataganas, Karen Kerr, Imanol Luengo, and Danail Stoyanov
Digital Surgery, London, United Kingdom

Background: Despite the high volume, surgery is non-standardized, and variations often occur in performance, delivery and surgical approach. Such variation can result in errors and complications that can potentially be avoided.

Technology Overview: A central digital ecosystem based on software and hardware to drive consistent surgical practice and assist toward the standardization of procedures through process and workflow understanding and mapping is being developed. Intraoperative displays present information on the current surgical phase. A hardware device, powered by AI, updates the phase-related information shown and also records the procedure. A web-based video platform stores the recorded video, automatically analyzed in real-time prior to upload.

Potential Application in Surgical Simulation and Education: This technology enables sharing of surgical workflow information pre-, intra- and postoperatively via the Touch Surgery app, TS Pro. TS Pro offers an annotated video-sharing tool, which embodies the learn and test mode of the TS academically validated app, to enable online learning. Preoperatively, surgeons will share their surgical workflow and preferences with their teams, to drive learning and preparation for upcoming surgical cases. Intra-operatively, the AI-powered hardware and displays will drive team coordination and enhance team performance, allowing team alignment at each phase of the operation. Postoperatively, the recordings of the procedure will be automatically uploaded to our web platform where AI algorithms extract different analytics and benchmarks that will drive standardization and discover best practices to share across surgical teams.

Potential Opportunities to Collaborate: Through sharing best practices, surgeons can collaborate within and between teams, to not only benefit the surgical trainees but the whole team, and specifically the scrub techs too. Trainees will have a novel education platform before, during and after the operation with procedural guidance content, including patient- and procedure-specific content and workflows through innovative digital tools and displays.

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A Call for Abstracts will be announced in late summer 2021.

Abstract Code | Abstract Category

P-01 Research

Novel Application of Reinforcement Learning to Automate Surgical Subtasks Rendered in a Virtual Soft-Body Simulation

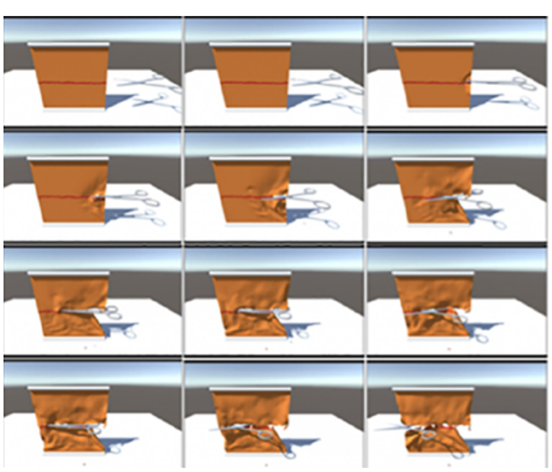
Alexandra Tan Bourdillon, BS; Animesh Garg, PhD; Hanjay Wang, MD; Joseph Woo, MD; Marco Pavone, PhD; and Jack H. Boyd, MD
Yale School of Medicine, New Haven, CT; University of Toronto, Toronto, ON; Stanford School of Medicine, Stanford, CA

Introduction: The revolutions in artificial intelligence hold tremendous capacity to augment human achievements in surgery, but robust integration of deep learning algorithms with high-fidelity surgical simulation remains a challenge. We present, to our knowledge, the first application of reinforcement learning for automating surgical dissection in a graphical simulation.

Methods: Using the Unity3D game engine, we integrated the "Machine Learning-Agents" Unity package with a graphical environment rendering a planar, deformable tissue modeled by Nvidia's FleX particle simulator (uFlex package). Our network comprised 2 hidden layers and 128 hidden units. Proximal Policy Optimization rewarded tissue collision along the desired path, simulating dissection. TensorFlow analytics informed hyperparameter tuning; constant and proportional rewards were evaluated. Task automation consisted of two stages: one-dimensional motion (forward and backward) followed by two-dimensional (adding lateral movement).

Results: In the first stage with one-dimensional motion, a downward trend in loss values was achieved. Episode length significantly decreased over 30,000 steps ($p < 0.001$, $R^2 = 0.38$) and better performance was obtained using constant rewards compared to proportional rewards ($p<0.05$, $R^2 = 0.32$). In stage two allowing for two dimensions of freedom, cumulative reward progressed slightly over 50,000 iterations ($p = 0.17$) and the rate of accomplishing the simulated task approached 50% completion. Entropy of the agent's actions increased and then decreased over the training period ($p < 0.001$, $R^2 = 0.67$).

A



B

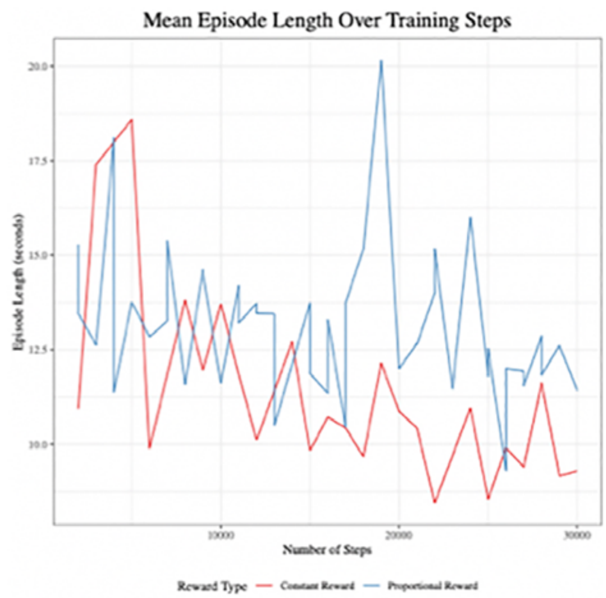


Figure. Agent scissors autonomously cut deformable tissue in a virtual environment (A). Training with constant rewards rather than proportional rewards achieved better performance, as seen by greater decreases in episode length (B).

Conclusions: This work marks a promising methodology to develop automated programs for performing surgical subtasks, but further work is needed to enhance simulation complexity and computational performance. Ultimately, advancements in computer vision will allow for the translation of virtual algorithms in the physical world.

P-02 Promoting Technology and Collaboration

A Rapid Development Platform for Modular, Mixed, and Augmented Reality Simulators

Samsun Lampotang, PhD, FSSH; William Travis Johnson, BS; Andre Bigos; David Lizdas, BS; Lauren Blakemore, MD; and Stephanie B. Ihnow, MD
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Background: Simulators for learning various procedures often share common elements (e.g., tracked ultrasound probes for TEE, TTE, FAST, venous access) resulting in similar, redundant development effort. Simulation technology may become more affordable with modular design. We describe the SMMARTS (System of Modular, Mixed & Augmented Reality Tracking Simulators) open architecture, rapid simulator development platform.

Technology Overview:
A modular stand provides mechanical indexing (registration) of a discrete block representing the anatomy relevant to the simulated procedure. A software development kit (SDK) integrated with the modular stand and a set of hand-held tracked tools such as a needle and ultrasound probe facilitates software development.

The SMMARTS SDK *(https://github.com/UF-CSSALT/SMARTS-SDK)* developed in Unity Technologies' Unity game engine consists of features to facilitate the development of medical simulators. SMMARTS includes an Arduino microcontroller and Ascension Technology Corporation's 6DOF tracking connectivity along with software tools like a replayer feature, user interface templates, 3D model visualization, scoring monitors, cognitive aids, common error messages, and Experience API LMS compatibility.

Potential Application in Surgical Simulation and Education: The SMMARTS platform has been used to develop simulators in our lab (ventriculostomy-EVD, epidural loss-of-resistance, instructor-less central venous access, TRUS prostate biopsy, pterygopalatine fossa block, lumbar/chronic pain blocks, intravenous access, and chest tube insertion) and externally (hardware front-end to practice psychomotor skills for a third-party screen-based simulator). A potential application is US-guided hip effusion biopsy for orthopaedic surgery and other fluid and tissue biopsies. SMMARTS can currently track a Kelly clamp and can be extended to track other surgical instruments.

Potential Opportunities to Collaborate: As an open architecture platform that has been used to develop multiple compact, deployable, turnkey simulators including one currently deployed in Iraq, SMMARTS is available for use by third parties to rapidly develop simulators for new procedures including surgical ones and also extend SMMARTS platform capabilities.

P-03 Research In-Progress

Training Simulator for Extra-Corporeal Membrane Oxygenation (ECMO)

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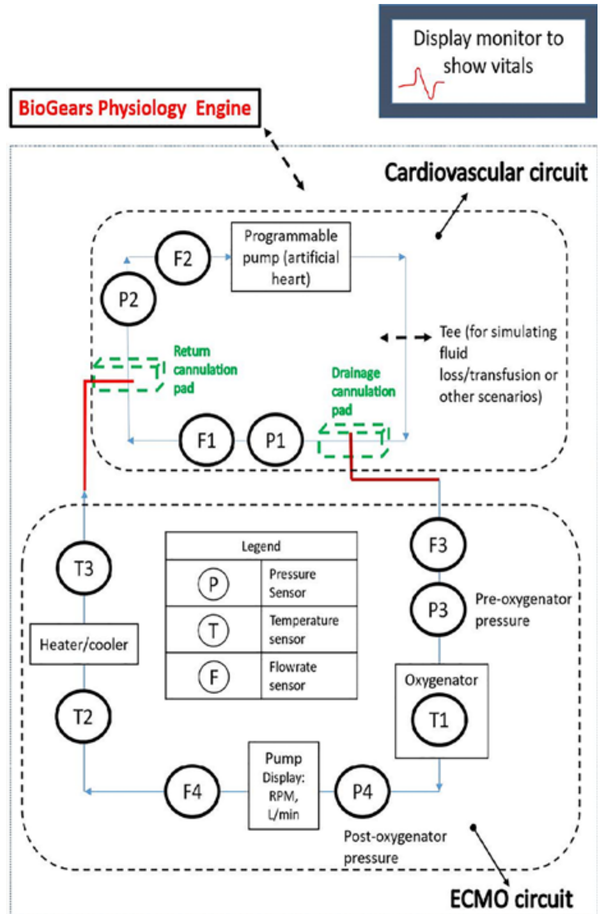
Introduction: Extracorporeal Membrane Oxygenation (ECMO) is a life support procedure that enables the bypass of heart and lungs in case of severe cardiogenic shock and respiratory failure. Traditional ECMO training is focused on didactic lectures, hands-on training with ECMO equipment and discussion. It is thus imperative to develop a training simulator that trains on this procedure and the complications associated with it. In this abstract, we present the design of a training simulator we developed for ECMO that will train the medical professionals acquire the skills required to perform this procedure on real patients.



Methods: The training simulator developed has three main parts: (1) cardiovascular circuit that has a programmable pump to mimic the human heart and produce physiological fluid output. It has replaceable cannulation pads to perform cannulation and a synthetic vasculature. (2) ECMO circuit that has an external pump to regulate the simulated blood and different sensor probes such as flow, temperature and pressure to monitor the vitals thus simulating the ECMO procedure and (3) interfacing the task trainer with the human physiological model to simulate different clinical scenarios like hypovolemia, hypoxia, etc.

Preliminary Results: The cannulation pad developed to perform cannulation was proven to be ultrasound compatible. Also, the oxygenation procedure (from deoxygenated to oxygenated blood) was successfully simulated using a blood simulation. A sample case of hypovolemia was simulated by integrating this system with the virtual physiology engine. Results showed that the decrease in blood volume due to hemorrhage scenario caused the programmable pump (artificial heart) to run faster thus representing faster heart rate.

Next Steps: The next step is to validate the simulator and develop a curriculum that will give access to trainees to evaluate and treat a simulated patient using the ECMO simulator. This will include cannulation, initiation and management of a simulated patient.

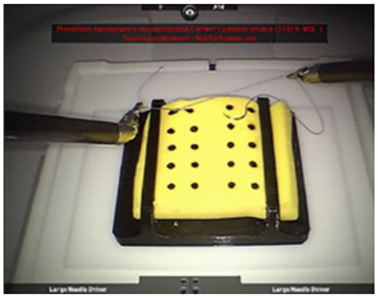
P-04 Research In-Progress

Kinematic and Kinetic Task Performance Data for Holistic Assessment of Skill at Robot-Assisted Minimally Invasive Surgery

Sergio Machaca; Rachel M. Haupt; Anand Malpani; and Jeremy D. Brown
Johns Hopkins University, Baltimore, MD; University of South Carolina, Columbia, SC; Johns Hopkins University, Baltimore, MD

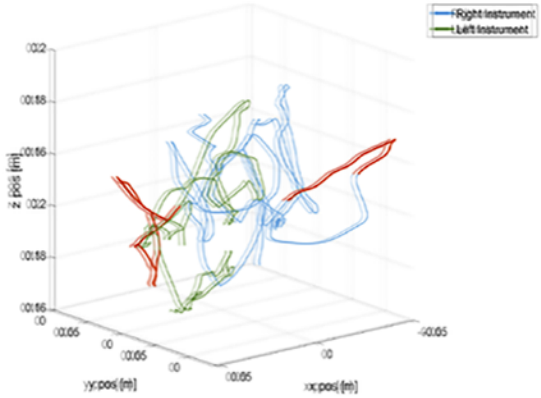
Introduction: As robot-assisted minimally invasive surgery (RAMIS) becomes the standard of care for many surgical specialties, there is a growing need to ensure that all robotic surgeons have the same fundamental level of skill proficiency. Current clinical training and assessment, in particular with the real clinical robot, focus more on reducing the observable egregious errors like breaking a suture or tearing tissue, and less on the underlying psychomotor behaviors that lead to these egregious errors. Recent skill assessment efforts have separately focused on the motion of the surgical tools (kinematics) or their physical interactions with the surgical environment (kinetics). The ideal skill assessment platform, however, should consider the interplay between the two, given their interdependence in psychomotor skill proficiency

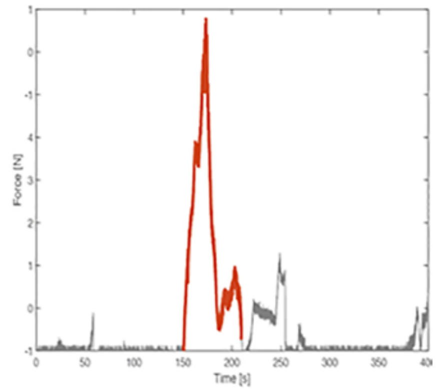
Methods: We have developed a data acquisition platform that is capable of measuring time-stamped kinematic and kinetic task performance data from a da Vinci surgical system, as well as the video feed from the robotic endoscope. Joint-level kinematics of the robot are provided by the da Vinci Research API. Kinetic data is provided by accelerometers attached to the robotic instruments and robotic endoscope, and a force sensor placed underneath the training task.



Preliminary Results: As demonstrated in the Figure, our platform is capable of measuring the kinematic and kinetic task performance data that are time-synced with the video frames from the robotic endoscope. For this example suturing task, we highlight the 3D trajectory of the robotic needle drivers as well as the forces produced on the suture pad while the participant attempts to tie a surgeon's knot.

Next Steps: We will collect task performance data on basic psychomotor skills tasks from clinical participants of varying skill proficiency. Ground truth labels of skill performance will be generated using crowdsourced methods, and machine learning algorithms will be trained to predict skill according to the GEARS structured assessment.





P-05 Promoting Technology and Collaboration

A Common Language Introducing SNOMED Is Essential for Simulation Training

Harald Scheirich, MSCS; Timothy Kelliher, BSEE; Ryan Kornheisl, BS; and Howard R. Champion, MD, FACS
SimQuest, Annapolis, MD

Background: A common language for multiple simulator interaction is the future of technology assisted training which in turn is essential for individual and team training. The fundamental underpinning for the future of simulation and technology-based training is the ability of various sources (and industry products) to interrelate. Current technologies are not interoperable, and no standards exist to enable interoperability. This lack not only affects engineers attempting to build heterogenous technological training environments but also educators and administrators that want to reuse, comprehend, and analyze the data in these systems. This requires a common language describing medical conditions.

Technology Overview: At the core of creating an environment supporting dynamic interoperability is a nomenclature that is both understandable to the humans using these environments and the computers running within. Problems this nomenclature needs to be able to address are amongst others: defining medical cases, being able to understand data streams that are emitted from simulation systems, correctly labeling and processing the large variety of medical procedures and actions, and interpreting and assessing the results of an individual and team learners progress through a collection of scenarios. SNOMED-CT has a nomenclature, and a system of terms already spanning a large area of medicine that is both human and computer readable, it is well suited to serve as a lingua franca for information exchange between computers during a simulation and also supporting solving other challenges that occur when addressing understanding complex medical training.

Potential Application in Surgical Simulation and Education: We are using SNOMED-CT an international open standard, as a basic language for the Medical Simulation Training Architecture, MSTA, for the U.S. Army and will use this to link their medical simulation centers to the Department of Defense's Synthetic Training Environment and to civilian training systems. A brief characterization of SNOMED-CT and its application into these domains will be given.

Potential Opportunities to Collaborate: Simulation software companies.

P-06 Challenges in Surgical Education

Bridging the AI Chasm in Surgical Simulation: Are Surgeons and Engineers Sufficient?

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Background: Machine learning and Artificial Intelligence (ML & AI) methods are critical for advances leading to next generation surgical simulation.

Current Challenges: Despite the enormous potential ML & AI methods hold for technology-enhanced surgical education, one major challenge limits its advance—the critical need to educate surgeons and engineers with cross-disciplinary concepts to enable effective collaborative research. Specifically, surgeons must understand fundamentals of data science for AI in surgical education. On the other hand, engineers must understand how technology to enhance surgical education are evaluated; this includes study design, bias, validation methods, and how technology impacts outcomes in surgical education. This talk will illustrate these ideas, discuss an online course addressing this challenge, and identify other relevant resources that currently address them.

Need of Innovation Introduction: Scalable resources are necessary to build capacity in the form of multi-disciplinary teams for research on technology-enhanced surgical education. To address this need, we are developing an online course on fundamentals of data science for AI in health care. This talk will explain the challenge as a chasm between technology development and its effectiveness and utility in real-world training curricula, introduce the learning objectives for our course, and provide information on accessing it.

P-07 Research In-Progress

Motion Tracking Accurately Distinguishes Trainee Experience in Laparoscopic Surgery

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Introduction: Caseload reduction of surgical residents has resulted in increasing demand for simulation to assess surgical competence. Current assessment in laparoscopic simulation is based on time-per-task. Real-life assessment also includes economy of motion and working volume but is rarely used outside of robotic simulators. We investigated the role of motion-tracking software in the assessment of technical proficiency in laparoscopy.

Methods: Using a motion tracker (Polhemus Patriot, Colchester, VT, USA) attached to surgical instruments, we captured motion (60 Hz) from subjects completing a standardized Fundamentals of Laparoscopic Surgery (FLS) task. Data was passed through a Savistky-Golay filter to reduce background "noise" and tremor and was analyzed using custom-built software to measure task time, path length, movement count, and working volume. Data was converted to visual representation of continuous movement from task start to finish.

Preliminary Results: 34 students and 14 residents were recruited. Training levels ranged from second-year medical school to fourth-year post-graduate year (PGY4) residency. Performance of an FLS exam proctor was used as the mastery benchmark. Residents had shorter time (45.6 ± 8.5s vs 241.8 ± 100.9s, p=<.001), shorter distance (47.5 ± .8.4cm vs 121.9 ± 56.3cm, p=.004), and faster speed (1.0 ± 0.2cm/s vs 0.5 ± 0.1cm/s, p=<.001) compared to students. Differences were detected in movement count (31 ± 7.02 vs 43 ± 26.5, p=1.0) and working volume (3.4 ± 1. cm^2 vs 5.1 ± 2.9cm^2, p=0.19) but were not statistically significant. Movement tracings were easily distinguishable between novice (student), intermediate (resident) and expert (FLS proctor) levels (Figure).

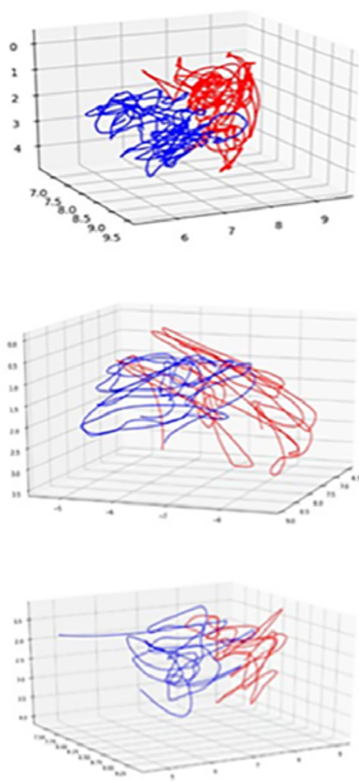

Figure. Motion tracking graphs for students, residents, and FLS exam proctor from top to bottom, respectively.

Next Steps: The custom-built software needs to be externally validated by others to confirm content validity and incorporated into simulation training to provide immediate feedback after each trial. The new approach will be valuable if it can demonstrate greater learning efficiency that standard simulation training without motion-tracking.

P-08 Research

Bimanual Wrist-Squeezing Haptic Feedback Changes Speed-Force Tradeoff in Robotic Surgery Training

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Introduction: Without haptic feedback, safely handling tissue with the robotic instruments can be challenging for novice trainees. While most surgical training paradigms focus on maximizing speed and minimizing tissue interaction forces, task completion time is often the primary performance metric. We hypothesize that providing novices with tactile feedback of the force magnitude they apply while training will significantly reduce their root-mean-square (RMS) force magnitudes while not increasing their completion time compared with trainees receiving no feedback.

Methods: Novice participants with little to no prior da Vinci or clinical experience ($n = 20$) performed a ring rollercoaster training task 12 times using a da Vinci S surgical robot. Participants were instructed to finish each trial as quickly as possible. Participants in the feedback group ($n = 10$) received haptic feedback for all 12 trials, delivered bimanually by wrist-squeezing tactile actuators.Participants in the control group ($n = 10$) completed all trials without haptic feedback.

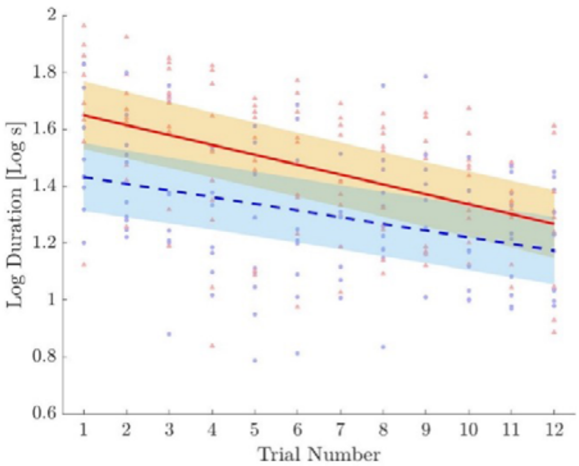

Figure 1. Log-transformed task completion time (left) and log-transformed RMS force (right), by feedback condition. Red markers and fitted line represent the feedback group. Blue markers and fitted line represent the no feedback group.

Results: The feedback group produced significantly less RMS force than the control group ($p = 0.03$). Neither group significantly changed their RMS force throughout the experiment ($p > 0.05$). At the start of the experiment, the feedback group was significantly slower than the control group ($p = 0.01$). The no feedback group significantly reduced their task completion times throughout the experiment ($p < 0.01$), and the feedback group reduced their task completion times significantly faster than the control group did ($p = 0.03$).

Conclusions: Providing novice da Vinci users with tactile feedback of the forces they exerted had no significant effect on final task completion time and significantly reduced the applied forces. This could potentially reduce tissue damage and suture breakage in clinical settings later on.

P-09 Challenges in Surgical Education

Use of Technology to Address Current Challenges in Surgical Education

Elizabeth M. Huffman, MD, and Dimitrios Stefanidis, MD, PhD

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Background: Innovative application of technology into training curricula and instructional methods may enhance the ability of surgeons to provide effective education to their learners, especially in the era of restricted resident duty hours. Simulation is perhaps the most recognizable integration of technology into surgical education, but other solutions such as e-learning, virtual reality, and smart phone applications provide examples of technological application into surgical curricula. Despite the proliferation of technology use in surgical education, however, several challenges remain that may benefit from novel technological solutions.

Current Challenges: To identify current challenges in surgical education that could benefit from the incorporation of technology, we surveyed surgical educators and human factors engineers who work collaboratively in our institution. Participants were asked to provide their suggestions and ideas on challenges faced in education and education research that could potentially be addressed by using technology. Responses were analyzed and common themes identified.

Need of Innovation Introduction: Eight group members responded. Aspects of surgical education that were suggested which could benefit most from integration of technology included ways of streamlining the acquisition and sharing of performance assessment data from multiple domains of skill (technical, nontechnical, affective) particularly by adding automation in data acquisition, collation, and reporting for immediate performance feedback to learners and educators. Areas of education research in which respondents felt technology would help advance the field included creation of higher fidelity simulations, incorporation of augmented reality for improved simulation environments, and development of large databases with training and performance data that enable clinical performance to inform needs for simulator training and vice versa. Additional ideas explored the need for better methods of detecting high individual workload and interventions to monitor and improve trainees' non-technical skills. Identification of such needs for technological intervention can help set research agendas for integrated surgical and engineering research projects in the future.

P-10 Research In-Progress

Automated Surgical Video Analysis Using Multi-Task Learning

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Introduction: Recorded videos from laparoscopic procedures contain valuable information, which can be extremely useful in surgical education and training. To efficiently utilize these videos, important features such as the usage of surgical tools and different phases need to be extracted, which can be cumbersome to do manually and hence an automated system needs to be developed.

Methods: With the advent of deep learning, such tasks can be accomplished by training deep convolutional and recurrent neural networks (CNNs and RNNs) to learn the spatial and temporal visual features. We designed two Recurrent Convolutional Neural Networks (RCNNs) to identify the appearance of different surgical tool combinations and, the current phase of each frame of a laparoscopic video using the knowledge of five previous frames.

Preliminary Results: We tested our models on a dataset that contains 80 videos from laparoscopic cholecystectomy. We obtained frame-level accuracy of 79.97% for tool presence detection and 85.2% for surgical phase identification by separately training the RCNNs and further improved the performance by training RNNs at the post-processing step to 91.91% and 92.5% respectively.

Next Steps: The high correlation between the surgical tasks and the tools suggests an excellent potential of jointly training a deep learning model to simultaneously perform the two tasks. Our next step is to train our model with multiple tasks such as detecting the presence, location, and pose of surgical tools, surgical tasks or events, and anatomical structures in each frame of a surgical video. In order to accomplish this objective, the visual feature extractor will be shared among the various tasks, and multiple outputs will be taken to minimize multiple loss functions in the optimization algorithm. We believe using this technique can boost the performance of each task, while using a single deep learning system.

P-11 Research In-Progress

VR Arthroscopic Simulation Training and Financial Return

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Introduction: Virtual reality arthroscopy simulators were developed to improve the surgical skills of orthopaedic residents by providing a cost-competitive training opportunity in a low stress environment. These simulators, however, are expensive and typically require maintenance contracts. One simulator company advertises that every time the simulator is used, the residency program saves $200-$300. We hypothesize that orthopaedic residency programs that do not explicitly integrate an arthroscopy simulator in their training curriculum see low simulator usage and less cost benefit.

Methods: Log data were retrieved from VR arthroscopy simulators at multiple U.S. orthopaedic residency programs. The simulator log data were consolidated for each institution to find the total hours of simulator use. Additional metrics such as the average time of simulation and an annual breakdown of simulation time were computed. Each institution also provided information on how their curriculum incorporated simulator training, as well as when their VR simulator was available for training on residents' free time.

Preliminary Results: Of eight orthopaedic residency programs contacted, six have contributed to the initial results (Figure 1). The University of Iowa residency program utilized their VR simulator 26.8±25.2 hours per year over a five-year period. Factoring in the initial purchase price and annual maintenance costs for the simulator, each hour of simulator use cost $1,482. Institutions 1, 2, and 3 saw respective costs of $61,439, $3.545, and $4,152 per hour of simulation use. All institutions make their VR simulators available for use by residents at any time. Institutions 3 and 5 required that residents use the simulator as part of their residency curriculum.

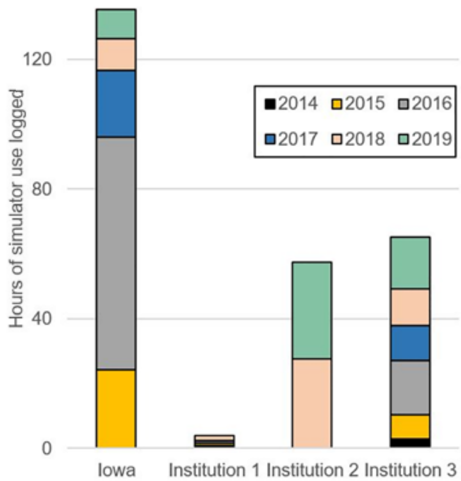

Figure 1. This chart shows the annual breakdown for hours of simulator use and how it varied by institution.

Next Steps:
Additional orthopaedic residency programs have been contacted to retrieve their VR simulator log data. All programs will also be sent a survey to determine detailed use of their simulator and specific simulator expenses for further cost benefit analysis.

P-12 Promoting Technology and Collaboration

From Scans and Model Collections to Interactive Surgical Simulation

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Background: Creating variants of virtual anatomy suitable for interactive simulation with force-feedback has been a bottleneck for creating relevant and engaging laparoscopic surgical training. Such modeling, as well as reconstruction of patient-specific anatomy, currently requires close interaction between medical specialists (e.g., radiologists) and computer aided design specialists (engineers). At present, few surgeons aiming to prepare their residents for active duty in the operating room or planning a complex surgical intervention can avail themselves of such an inter-disciplinary support team.

Technology Overview: The Toolkit for Illustration of Procedures in Surgery (TIPS) lowers the barriers to modeling and reconstruction especially of soft tissue. TIPS provides an interface for assembling simulation-ready pieces of anatomy (simlets) that a surgeon-educator can combine into a training scenario via a simple text-based editor; and a new external tool that leverages a VR environment to allow a surgeon to document their expert understanding of vascular connectivity by interactively generating valid, simulation-ready trees from patient-specific data that are too sparse for leveraging image processing tools.

Potential Application in Surgical Simulation and Education: Enabling surgeons to themselves design, adapt or customize anatomy for laparoscopic surgical training and surgical planning increases their involvement in driving and shaping the direction of surgical simulation and education. Assessment of impact on education and surgical planning are in progress.

Potential Opportunities to Collaborate: Prime partners for TIPS are surgical educators and surgeons planning anatomically complex interventions. Open source soft tissue simulation libraries, like SOFA and iMSTK, are natural collaborators who form the backbone of the actual simulation.

P-13 Research In-Progress

Establishing Performance Metrics on Pinning Pediatric Elbow Fractures: From Simulation to the Operating Room

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Introduction: Supracondylar humerus fractures are one of the most common pediatric fractures. A standard treatment approach is to fix the fracture by pinning it with three surgical wires spread across the fracture line under fluoroscopic guidance. We developed a novel simulator to train orthopaedic residents on this critical and difficult wire navigation skill. The goal of this work was to establish the validity of the new simulator by demonstrating performance differences between expert and novice orthopaedic surgeons working with the simulator and in the operating room (OR).

Methods: Simulator performance was assessed with 4 novice and 4 attending orthopaedic surgeons. Performance was measured by: (a) the spread of the wires at the fracture line, (b) the number of fluoroscopic images used while placing the wires, (c) and the duration of time spent. OR performance on pinning pediatric supracondylar humerus fractures was assessed on any relevant case from January to October of 2019, in which all fluoroscopic images acquired during surgery were saved. This allowed for a postoperative analysis of the performance using the same metrics as were used for the simulator.

Preliminary Results: On the simulator, experts demonstrated greater pin spread at the fracture line and used fewer images than novice surgeons. The OR data revealed almost no correlation between the number of images used and the pin spread of the surgeon, suggesting these metrics are independent of one another and can be combined to form a composite score.

Next Steps: We will take new residents through a curriculum on the simulator before they enter the OR. Then we will measure their performance using the newly validated metrics and compare their skill level with previous data on residents that hadn't practiced on the simulator. This will demonstrate if training on the simulator can improve performance in the OR.

P-14 Promoting Technology and Collaboration

The Advanced Modular Manikin Developers Kit

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Background: As part of the Advanced Modular Manikin (AMM) project, our team created a number of AMM platform prototypes. These prototypes were in the human form. To provide interested parties with a tool for AMM compatible module development a reference design integrating all AMM Central Operating REsources or C.O.R.E. into a single non-manikin unit was created.

Technology Overview: AMM C.O.R.E. runs all required software, provides system resources and allows connection of one external AMM module. The self-contained unit is powered from 120VAC mains. It provides pressurized air, two individual fluids and a waste line to an external AMM module according to the standard fluidics specifications. The compute platform consists of an AMMDK embedded system to control the fluidics system and a Network Manager embedded system to run the AMM system software, provide networking services and PoE power injection for the AMM connector. Service access to fluids is separated from power equipment and electronics.

Potential Application in Surgical Simulation and Education: The AMM C.O.R.E. represents a full implementation of the AMM 1.0 standards, ready for developers that have an interest in developing new plug in modules that are AMM compliant. To date different groups have created modules as diverse as a fasciotomy leg, IV arm, intubation head, various tablet based medical devices, such as a virtual ventilator, IV pump etc. The AMM open standards platform is being published under Creative Commons as open source allowing developers to benefit from the DoD's investment in open source simulation tools that can be built upon reducing time to market and considerable savings in R&D.

Potential Opportunities to Collaborate: The CREST team at UW is continuing work to create new modules and collaborate with both Industry and Academia. Furthermore, new funding opportunities are available from the DoD to build upon this platform.

P-15 Challenges in Surgical Education

The Role of Virtual Reality in Bridging the Gap in Surgical Training

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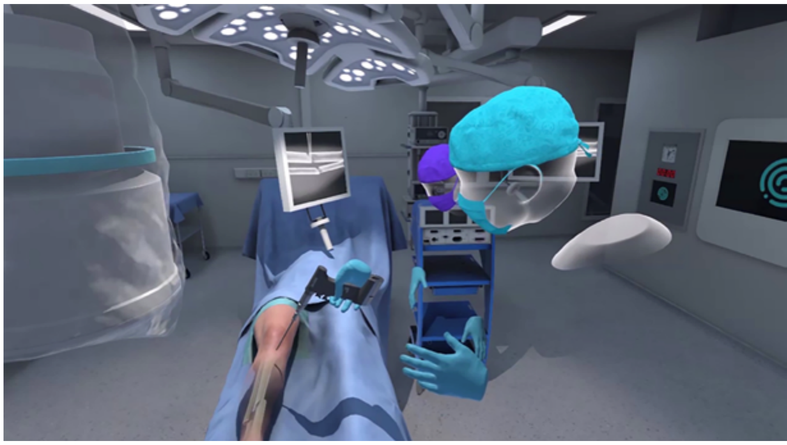
Digital Surgery, London, United Kingdom

Background: Despite advances in technology over recent decades, surgical education is still often delivered using traditional printed materials and methods such as the "See one, do one, teach one" model. This apprenticeship model is no longer appropriate as it cannot reliably monitor or predict the output of a training program. Online and mobile training materials are generally limited to teaching cognitive skills and surgical process.

Current Challenges: Hands-on training time is increasingly reduced for trainees. Access to high end clinical training simulation labs and cadaveric training is expensive and limited. Paper-based and non-immersive online materials are generally restricted to teaching anatomy and surgical process. Textbook pages and mobile device screens are not well suited to recreating learning environments that match the real-world operating theatre.

Need of Innovation Introduction: There is a need to bridge the educational and experiential gap between textbooks, screen based learning and real-world experience. Immersive technologies



such as AR and VR can create risk-free, repeatable, recordable environments that resemble the real world and can provide both training for cognitive and psychomotor skills.

VR offers an attractive alternative to improve both cognitive and technical skills free of the demands of challenging clinical environments. It plays an important role and encourages diversity in educational portfolios by allowing residents to gain experience in procedures that would otherwise be inaccessible (Figure) In clinical practice, VR can facilitate manipulation of patient-specific data for perioperative use in order to optimize surgical planning and intraoperative support.

Further research is required to demonstrate the full utility and usability of VR in skills transfer. It has the capability to enhance the productivity of surgeons and consolidate resources without compromising patient safety.

P-16 Research In-Progress

A Virtual Reality Consumer-Level Haptic Epidural Simulator

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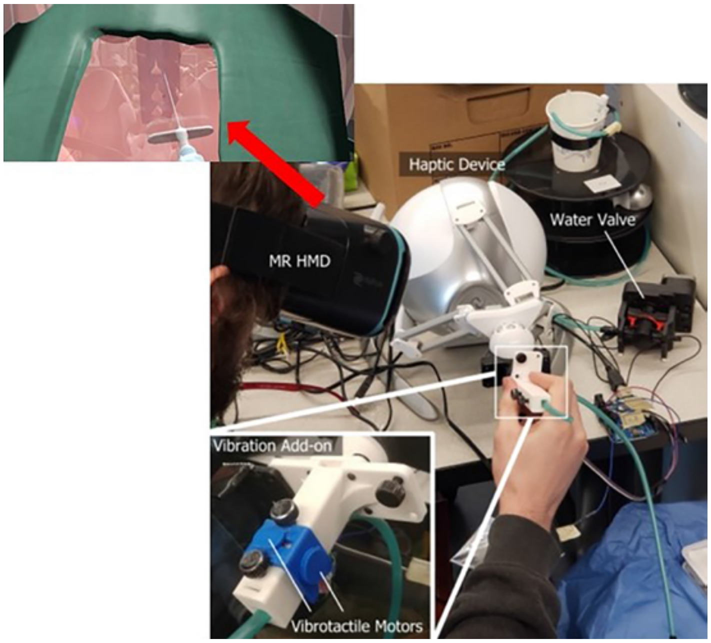
Introduction: Performing an epidural is a very complex and demanding task for an anesthetist to learn. Virtual reality (VR) and haptic simulators have the potential to provide cost-effective learning opportunities to improve epidural expertise, increase patient safety, and success rates. Here, we present the *Unity Simulator for Epidural Insertion Training* (USEIT), a VR-based haptic-enabled system for epidural training. USEIT implements a novel model that integrates a haptics library with VR visual feedback, and drug administration through an open electronics-controlled valve. The system employs off-the-shelf materials, 3D-printed parts and the freely available Unity game engine.

Methods: The user manipulates a Tuohy needle attached to a 3D-printed end-effector that is in turn attached to a consumer-level haptic device (Novint Falcon). Upon locating the point of insertion and penetrating the virtual patient's skin, the movement of the needle is locked perpendicular to its shaft axis by force feedback. If the insertion is poorly executed and the needle hits the backbone, the user is alerted via vibration. The system models the associated needle forces by simulating soft tissues utilizing a unique "mobile nonlinear spring" model. A syringe is attached to the Touhy needle, and a loss-of-resistance method is applied using an Arduino-controlled fluid-valve system that includes water/saline filled syringe simulating flow resistance to the drug administration (Figure). The user can be provided a visual feedback of the patient's back on a 2D display or with a stereoscopic 3D view using a head-mounted display.



Preliminary Results: No results available yet.

Next Steps: Technical report describing the system is in preparation. The next steps include examination of a) system usability, b) face, content and construct validity, c) efficacy and d) effectiveness. Concurrently, we plan to assess readiness for implementation, construct and study an implementation process using Consolidate Framework for Implementation Research.

P-17 Research In-Progress

Augmented Reality-Based Simulation Training for Extra Corporeal Membrane Oxygenation (ECMO)

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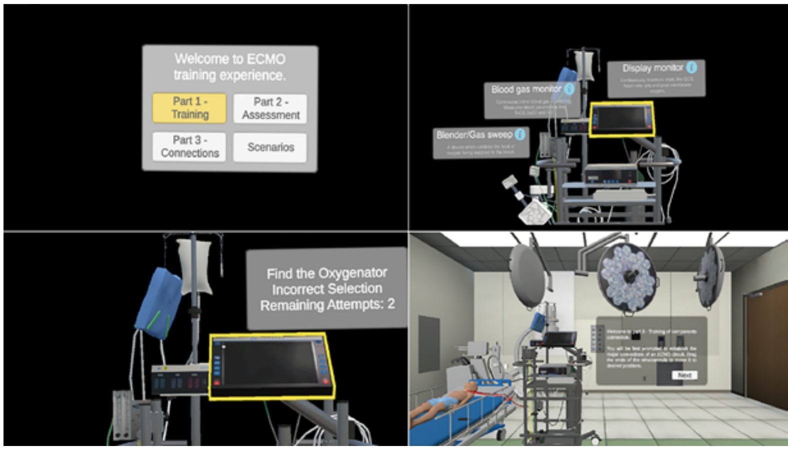
Introduction: Extracorporeal Membrane Oxygenation (ECMO) is a complex procedure that provides life support to patients with respiratory and cardiac failure. Managing patients in ECMO is challenging than conventional care and requires an understanding of the cardiopulmonary physiology and working of ECMO machine. Simulation based training can be an effective method to improve the knowledge and skills required to perform the procedure among novice trainees. We present an augmented reality application to train health care professionals obtain the skills to interact with the ECMO machine and succeed in performing the procedure.

Methods: An augmented reality based ECMO trainer is developed in Unity™ for the Microsoft HoloLens. The user interacts within the augmented reality environment using hand gestures. The objectives of the application are : (1) familiarize the users on identifying essential components of an ECMO equipment and practice establishing appropriate connections (2) simulate various scenarios to train on observing the alterations in the ECMO parameters and physiological vitals, thus making decisions to restore back the normal condition. (3) pre- and post-assessment sections to determine the knowledge level of the trainees.



Preliminary Results: In the preliminary phase, various scenarios associated with the ECMO procedure have been identified. The developed module consists of (1) a free exploratory mode where the learner can inspect the different components of ECMO machine followed by an interactive assessment. (2) the user then proceeds to the next module, which guides them through establishing connections in the ECMO circuit.

Next Steps: Future work will involve simulating various clinical scenarios thus enabling the user to understand the interaction with the equipment to resolve problems. We intend to perform a study with medical trainees comparing their learning and performance with and without augmented reality-based learning experience to study the efficacy of training.

P-18 Research

The Educational Effectiveness of Simulation Used in Open Surgery: A Systematic Review

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RCSI, Dublin, Ireland; UL, Limerick, Ireland; TCD, Dublin, Ireland

Introduction: The role of simulation to teach and access open surgical skills has become more prevalent in recent years. This shift to training outside the hospital setting is largely due to the decrease training hours secondary to the European working time directive (EWTD) and patient expectations. A number of primary research studies have explored the educational impact of these simulators. This systematic review synthesizes the totality of evidence with respect to the educational effectiveness of simulators used in open surgical training.

Methods: A systematic literature search was conducted in PubMed, Embase, Cinahl, Scopus and Web of science. Only randomized controlled trials (RTCs) were included that explored the educational efficacy of simulators used in open surgical skills teaching. The methodological quality of the included studies was assessed using the Cochrane risk of bias tool.

Results: Six RCTs were included from the 9,934 studies found. The methodological quality of the included studies was variable. Overall, the use of the simulators was more educationally effective compared with standard teaching of the skill without a simulator ($p<0.05$). Two studies showed that the simulator was as good as an animal model of much higher fidelity.

Conclusions: The methodological and clinical heterogeneity across the studies limited our ability to meta-analyze these findings. Further studies are needed to secure higher evidence for the educational value, validity and transferability of the skills to the hospital setting for all simulators in use in surgical training. In the interim, this systematic review adds positive encouragement to their use.

P-19 Research

Non-Technical Skills Evaluation of Medical Students through Objective and Subjective Measures

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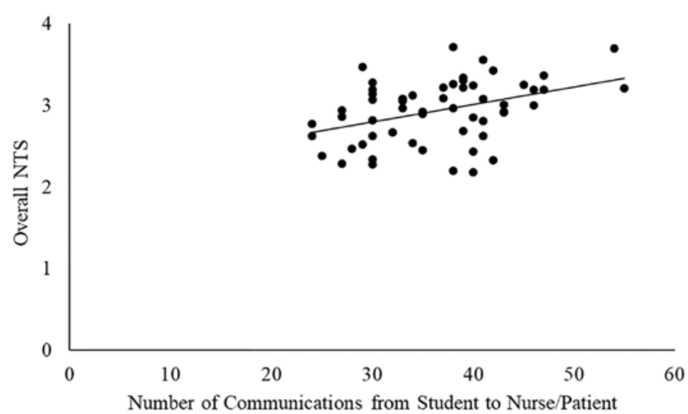
Introduction: Non-technical skills (NTS), particularly communication, have been found to impact clinical performance and outcomes. Current evaluation methodologies are subjective and depend on self or expert ratings. Wearable sensors and sensing technology may enable objective assessment of NTS. The objective of this study was to examine novel sensing approaches and preliminary models of automating NTS assessment. Our goal is to stimulate discussions between surgeons and engineers regarding objective factors reflective of NTS and how to capture them.

Methods: Fifty-seven third-year medical students participated in acute care team simulations (ACTS) and performed patient assessments by interacting with a nurse confederate and a high-fidelity patient manikin. Students' NTS was assessed by a clinician and a human factors engineer using an NTS assessment tool (0–6 scale; 6 representing model behavior) with the following NTS constructs: communication, situation awareness, cooperation, leadership, and decision making. A lapel microphone was used to record participants' audio. Speech and communication metrics (e.g., speech duration, ratio, intensity, rate, discourse between team members) were calculated. Pearson's correlation and multiple regression analyses were conducted to identify the relationship between NTS ratings and sensor metrics.

Results: The average overall NTS score was 2.9/6. Student' speech duration and intensity correlated significantly with the cooperation ($r=-0.30$, $p=0.021$) and decision making ($r=0.29$, $p=0.027$) constructs. The frequency of communication from student to nurse/patient (Figure 1) was also correlated significantly with average score ($r=0.40$, $p=0.002$). The relation of objective communication metrics with the overall NTS score using a multiple regression model yielded an r^2 of 0.21.



Conclusion: Objectively measured audio metrics were significantly correlated to expert ratings of communication, suggesting the feasibility of our sensing approach to quantify NTS. Future steps include integrating objective communication assessment into training and feedback for NTS training of residents.

P-20 Challenges in Surgical Education

Training Ultrasound-Guided Needle Insertion for Percutaneous Transhepatic Biliary Drainage

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University of Washington, Seattle, WA; California Polytechnic State University, San Luis Obispo, CA; U.S. Army Future Command CCDCSC STTC MSRB, Orlando, FL

Background: Percutaneous transhepatic biliary drainage (PTBD) is performed when there is an obstruction causing a buildup of bile in the common bile duct. This build up is often fatal if not addressed. PTBD is performed by using ultrasound (US) to guide the insertion of a Chiba needle percutaneously and into the bile duct. Using the Seldinger´s technique, a guidewire is then inserted through the stenosis into the duodenum, when feasible; otherwise, is left proximal to the stricture. A catheter or stent is then placed to promote drainage.

Current Challenges: Consistently and accurately placing the Chiba needle in the bile duct is difficult. This is a skill that must be practiced repeatedly and currently the only way to practice is on patients. Existing liver models are either able to be punctured and not ultrasound-able or ultrasound-able, but lack in training needle insertion. Many also do not have internal structures imitating the bile duct and the portal vein making it difficult to properly practice performing the procedure.

Need of Innovation Introduction: The ideal model meets five needs. The model should be anatomically accurate, with high fidelity biliary system. The internal anatomy should be visible under ultrasound and the vessels should be identifiable under Doppler supporting the inclusion of fluids. The model should simulate a biliary stenosis. The model materials should exhibit similar mechanical properties as human tissue. Finally, the model should be economical, supporting multiple uses and/or inexpensive production.

P-21 Research In-Progress

False Negative Proportions Increase with Template Deviation During Simulated, Systematic, Side-Fire Prostate Biopsy

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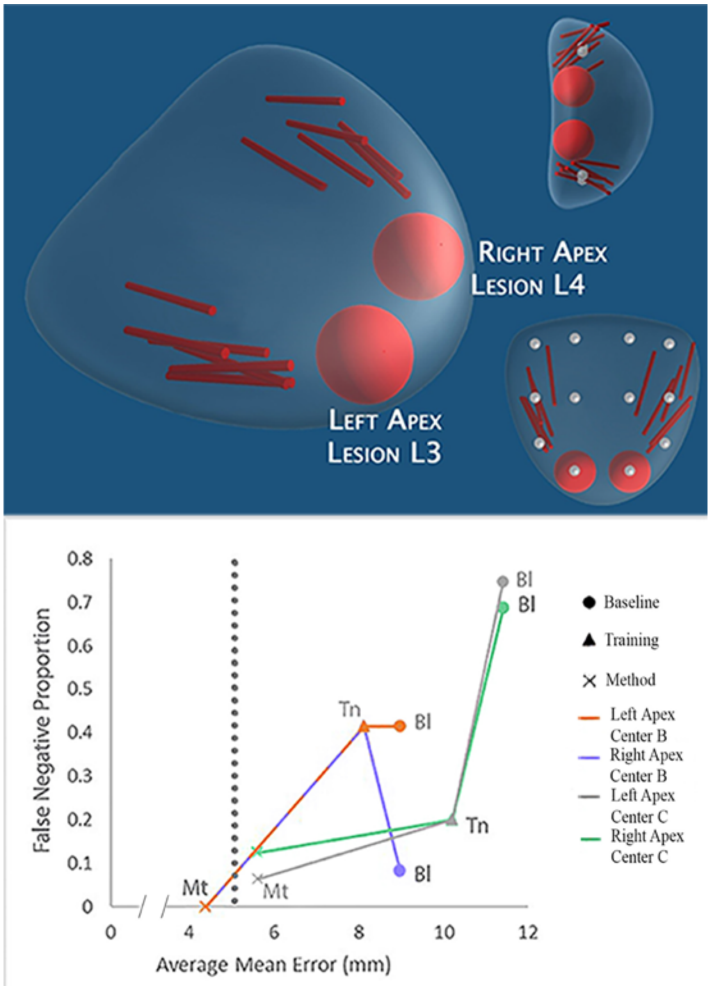
Introduction: During freehand systematic prostate biopsy (sPBx), it is difficult to distribute the cores according to sPBx templates. We call the average of the shortest distance between each core center and its intended template location "template deviation", a metric of how closely core centers match the template. sPBx false negatives (FN) range from 21–47% in patients. We investigated in a new simulator if sPBx template deviation is related to FN proportion.

Methods: Center B (n=12) and C (n=16) trainees performed simulated 12-core, double-sextant, side-fire, transrectal ultrasound (TRUS) sPBx. Baseline set Bl is before training; Tn after ~30 minutes training; Mt best score with continued training with a methodical technique. We placed virtual 4.9 mm radius spherical lesions, invisible with TRUS, at the right and left medial



apex of a simulated 24.4 ml prostate. Unless a core and a lesion intersect, however slightly, a FN occurs. We calculated FN proportion (# of false negatives/# of sPBx 12-core sets) for each center at conditions Bl, Tn and Mt.

Preliminary Results: For both lesions, template deviation and FN proportion in both centers are related ($p = 0.0015$). The fitted model: Odds of false negatives = exp(-2.84 + 0.22 x TemplateDeviation) On average, the odds of FN increases by 25% (95%CI: 8.9–43.4%) with each 1 mm increase in template deviation, not differing significantly between centers or lesions. All 12 center B trainees completed competency-based training (competency = template deviation ≤5mm). Only 12/16 C trainees came back for further training to reach competency (≤ 5 mm), explaining the C Mt deviation >5mm.

Next Steps: We will explore further the relationship between template deviation and FN proportions for other lesion locations, shapes and sizes, different prostate shapes and sizes for side-fire, end-fire and transperineal sPBx. We have applied for research funds to translate our findings to reduction of sPBx FN in patients.

P-22 Research In-Progress

Evaluation of Two Performance Assessment Modalities for a Novel Pediatric Cleft Lip Repair Simulator

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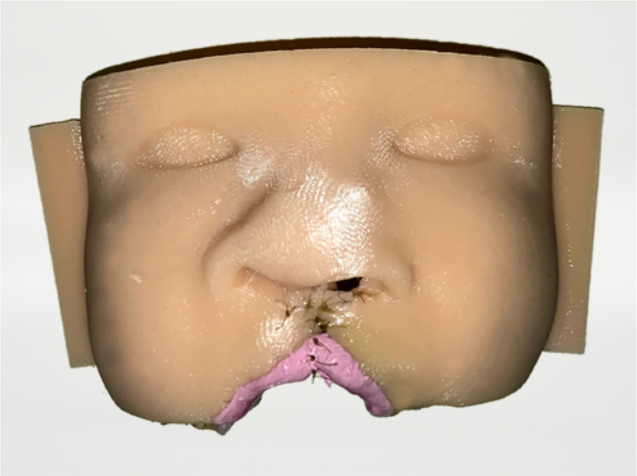
Introduction: With limited availability of pediatric surgical training models, trainees' exposure to pediatric procedures in otolaryngology and oral-maxillofacial surgery (OMFS) is limited to experiences in the operating room on patients. Traditional surgical teaching methods are not sufficient learning modalities for advanced procedures such as cleft lip repair (CLR). Using computer aided design and three-dimensional printing technology, pediatric CLR surgical simulators were designed and created along with web-based curriculum and assessment tools. Our earlier research demonstrated that the simulator improved trainees' performance. Continuing this work, we evaluated 2 procedural skills assessment modalities: a procedural video, and final photos of the completed CLR on the simulator for 5 trainees.

Methods: The course materials consist of a pre-module self-efficacy question (rated on 4-point scale) and 10-item multiple choice quiz, journal readings, video demonstration of the procedure, a post-module efficacy question and an online quiz. Five trainees submitted their performance video, and post-procedural photos of 3 different angles of the completed CLR. Performances and photos were rated by 2 otolaryngology and 2 OMFS faculty. Assessment tools consisted of 6 items on a 3-point scale and 1 global item, 'overall closure quality" (5-point scale). Mean ratings, inter-rater reliability, and practical aspects across modalities will be compared.



Preliminary Results: Learner self-efficacy ($p < 0.02$) and knowledge ($p > .05$) improved following training. Review of procedural videos and post-procedural photographs suggested training succeeds in increasing performance. Statistical comparison of rating differences and inter-rater agreement across assessment modalities will be reported in detail at the conference, and rater time commitment discussed.

Next Steps: The next steps are to further research the quality, cost, and benefits of both video and photo assessment methods. Future work will also expand this research to larger and more varied cohort of trainees and raters to evaluate the generalizability of these preliminary findings.

P-23 Research In-Progress

Building Blocks toward a Laparotomy Trainer

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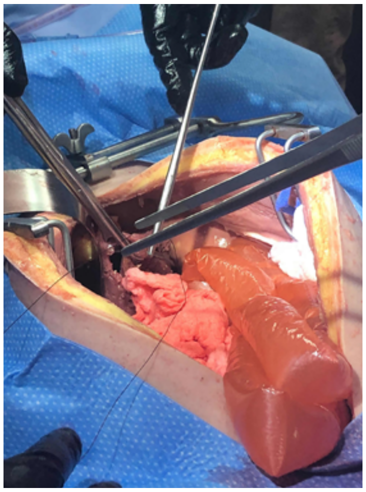
Introduction: Designing and building a laparotomy trainer that allows a surgical team to practice as a team, challenge all participants and provide meaningful feedback is a daunting task: it needs to bring together technical, decision making and team performance skills together in a unified platform. The Center for Research in Education and Simulation Technologies (CREST), under contract #W81XWH-14-C-0101 has developed a "Distributed, Modular, Interoperable" platform for health care simulation, called the Advanced Modular Manikin that supports all of these facets.

Methods: By working toward a System of Systems, following some basic design rules, we created a platform that allows for an almost open-ended expansion and supports collaboration between many developers and researchers: Key data traffic based on clinically relevant data. The "manikin" is a display for the state of the patient, regardless of instantiation: physical, virtual, or hybrid. Local issues are resolved locally, events that cause a systemic response are communicated to the core. Core does not know the inner workings of modules. Modules are not aware of each other, but of patient.

Preliminary Results: The various building blocks that connect to the AMM platform made it possible to create a Laparotomy trainer that brings together technical, decision making and team performance skills. The Laparotomy insert allows team members to collaborate on technical skills. The various cues provided on the ventilator, patient monitor, as well as, controlled bleeding in the abdominal cavity elicits ongoing decision making and finally the interplay between patient management by the anesthesiologist and progress of the surgery via the physiology engine requires team interactions on an ongoing basis. All required modules have been built and the system will be evaluated in the field.



Next Steps: With the first release of the AMM platform as open source behind us, the team is looking forward to the next few projects, targeting modules specific to complex trauma cases on the military side, and training for recovery from iatrogenic injuries in rural hospitals on the civilian side.

P-24 Promoting Technology and Collaboration

Parallel Development of Physical and Virtual Simulators for Image-Guided Biopsy

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Background: Traditionally, image-guided soft tissue biopsy phantoms involve a combination of explanted tissue with olives or raisins as targets. Although inexpensive, shelf life is short, and these phantoms are limited to a single imaging modality. Other simulators have employed techniques such as VR and haptic feedback to replicate the biopsy experience but have limited users' visual field and instrument selection thus minimizing training fidelity and usage. Our team has developed a low-cost multi-layered biopsy simulation model which allows for the use of several imaging modalities and can be used with instruments intended for clinical use.

Technology Overview: Our team was tasked with developing a multi-layered modular biopsy simulator o complement and pair with an augmented reality (AR) project for image-guided biopsy training. Thus, we created interlocking discs of Medical Gel (Humimic, Greenville, SC) to simulate various tissues within the abdomen. The discs can vary in thickness and density (shore) and can be interchanged to better mimic unique patient anatomy. The discs can also be rotated at discrete angles to change the position of the target to match the available images in the AR component.

Potential Application in Surgical Simulation and Education: This technology could be applied to any specialty that requires training for image-guided needle biopsy procedures.

Potential Opportunities to Collaborate: We welcome collaboration following completion of project and evaluation of preliminary validity evidence.

P-25 Research

Lessons Learned from Eight Years of Robotic Surgical Simulation and Directions for the Future

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Introduction: This study was done to evaluate trends in Robotic Surgery VR simulation from 2011 to 2019 to determine which categories of exercises are most utilized by students with a view toward predicting the next generation of Robotic Surgery VR training simulation.

Methods: Data from 455,300 VR robotic surgery exercises sessions, 416,000 sessions on the Mimic dV-Trainer®, 33,000 sessions on the Intuitive Surgical DVSS®, and 6,300 sessions on the newer portable Mimic Flex-VR® trainer from 2011 - 2019, were analyzed. Simulation exercises were broken down into four major categories: 1. "Basic" Robotic Controls (typically hand only activities), 2. Exercises focusing on "Foot Controls" (Clutching and camera movement), 3. Exercises focusing on "Fine Controls" (Sewing and knot tying), and 4. "Other" advanced exercises (Procedure Specific Simulation, Team Training and Games).

Results: On all simulators, "Basic Control" exercises were initially the most frequently performed exercises over the entire study period. But with all simulators, this utilization decreased steadily over time. "Foot Control" exercises remained either steady or decreased slightly. "Fine Control" exercises increased steadily over time. With all simulators, there was an increase initially in procedure specific exercises, but then this utilization stabilized and eventually even declined.

Conclusions: Over time, students consistently chose exercises that focused on the core psychomotor skills necessary to become proficient at robotic surgery (&gt 85%). The recent availability of procedure specific VR simulation showed some initial interest, but then utilization stabilized or declined over time. This shows that there is a continued need for core skill training in robotic surgery simulation. Partial procedure steps tied to specific core surgical skills training may be useful. These findings should help guide the development of future robotic surgery simulation training modules.

P-26 Challenges in Surgical Education

Digitising Surgical Process for Shared Online Learning

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Background: Surgeons need to continuously learn and improve; review, assessment and revalidation of performance is critical. Currently, this is relatively cumbersome and there is little standardization across specialties and health care providers.

Current Challenges: Surgeons are unable to track their performance over time, which makes standardization of surgery and sharing of best practices challenging. Surgical record keeping is inadequate and there is a lack of secure and usable storage solutions. There is no clear standpoint in health care for digital data acquisition and utility. Trainees have restricted hands-on operating time, and there are limited technological solutions that they can use to rehearse and assess ahead of 'real-time' operating. There are no standard solutions to track trainees' performance and progress over time, making it difficult to evaluate performance quantitatively.

Need of Innovation Introduction: Novel technology is required to enable the sharing of best practices, monitoring and performance review. We built TouchSurgery Professional (TSPro), on top of the globally recognized and validated simulation-based training platform, Touch Surgery. TSPro, a web platform for surgical video data storage, annotation and dissemination, is designed to allow surgical professionals to have access anytime, anywhere to documentation and training materials of previously performed cases. TSPro allows quick and easy labelling and annotation of surgical video data, provides searchable video content of complicated or interesting cases. As well as annotation of different phases/ steps of the operations for access and video streaming. In addition, since manually annotating every single surgical case is time consuming, TSPro supports AI-powered automatic annotation of a subset of surgical procedures. This automatic annotation is based on a novel surgical nomenclature designed to drive standardization and facilitate the sharing of experiences and best practices across teams. This provides trainees with access to a large surgical library of annotated cases to learn from and compare against.

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Meeting participants have asked for exhibitor involvement.
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VISIT *https://www.surveymonkey.com/r/SIMSEM03_2021*
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We offer you our sincere thanks for attending this meeting and we hope you have gained beneficial insights and inspiration from this dialogue and activity.

We welcome your input.
Please contact **Gyusung Lee, PhD**, at glee@facs.org or 312-202-5782 with any questions, comments, and suggestions to benefit the planning of future meetings.

SAVE THE DATE: MARCH 2, 2022 *Swissôtel CHICAGO, IL*

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