Multi-institutional Evaluation of Producing and Testing a Novel 3D-Printed Laparoscopic Trainer

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OBJECTIVE To create, distribute, and evaluate the efficacy of a portable, cost-effective 3D-printed laparoscopic trainer for surgical skills development.

METHODS The UCI Trainer (UCiT) laparoscopic simulator was developed via computer-aided designs (CAD), which were used to 3D-print the UCiT. Once assembled, a tablet computer with a rear-facing camera was attached for video and optics. Four institutions were sent the UCiT CAD files with a 3D-printer and instructions for UCiT assembly. For a comparison of the UCiT to a standard trainer, peg transfer and intracorporeal knot tying skills were accessed. These tasks were scored, and participants were asked to rate their experience with the trainers. Lastly, a questionnaire was given to individuals who 3D-printed and assembled the UCiT.

RESULTS We recruited 25 urologists; none had any 3D-printing experience. The cost of printing each trainer was $26.50 USD. Each institution used the Apple iPad for optics. Six of eight participants assembled the UCiT in < 45 minutes, and rated assembly as somewhat easy. On objective scoring, participants performed tasks equally well on the UCiT vs the conventional trainer. On subjective scoring, the conventional trainer provided a significantly better experience vs the UCiT; however, all reported that the UCiT was useful for surgical education.

CONCLUSION The UCiT is a low cost, portable training tool that is easy to assemble and use. UCiT provided a platform whereby participants performed laparoscopic tasks equal to performing the same tasks on the more expensive, nonportable standard trainer. UROLOGY 124: 297−301, 2019.

The demands of surgical training have changed over the past few decades requiring surgical trainees to acquire increasingly greater skills in less time. This is particularly true regarding complex surgical modalities such as laparoscopy and robotic-assisted surgery. Changing training needs prompted the Society of Gastrointestinal and Endoscopic Surgeons (SAGES) to develop the Fundamentals of Laparoscopic Surgery (FLS) curriculum. Indeed, incorporating a laparoscopic training curriculum is essential for surgical training, as is the objective assessment of those skills.[1,2] To augment training within the FLS curriculum, the FLS trainer system was developed, however the cost of this system ranges from $1164 to $6510 USD depending on the package contents and features purchased.[3,4] Furthermore, traditional laparoscopic trainers are typically stationary (due to their optics systems and bulk) and thus are usually only accessible within a designated surgical training laboratory. As such, trainees typically have varying degrees of access to these trainers.

Recognizing the limitations of contemporary trainers and the negative impact on accessibility for training purposes, we designed a portable, inexpensive, and easily assembled 3D printed trainer. The UCI Trainer (UCiT) is paired with a tablet-PC for optics and can be paired with any laparoscopic instrumentation available to the user. Following a successful feasibility test at our institution,[5] we sought to ascertain the ease of disseminating the UCiT design to other institutions for 3D-printing and subsequent training at their institution. Additionally, we had study participants compare the UCiT to traditional trainers.

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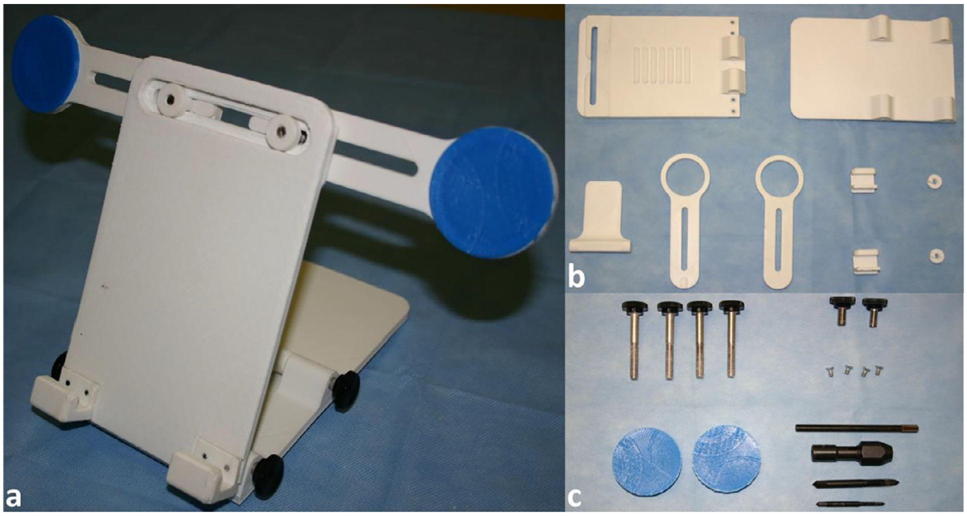

Figure 1. (a) Full assembled UCi Trainer, (b) 3D printed UCiT components, (c) Nonprinted UCiT components. (Color version available online.)

MATERIALS AND METHODS

We created the UCiT to function as a portable laparoscopic training device; it was designed to be lightweight and collapsible such that UCiT is small enough to fit in a lab coat pocket (not accounting for the laparoscopic graspers, needle drivers, etc.) and capable of being docked with any tablet computer for the video optics thereby simulating a laparoscopic environment (Fig. 1a-c). The two retractable arms are incorporated into the design to properly space the access "ports" and further simulate the laparoscopic environment. We began by developing the UCiT parts using computer-aided designs (CAD) via SolidWorks Software (Dassault Systems, Concord, MA). The CAD files for each individual UCiT part were subsequently 3D-printed, and the parts were then pieced together to create the functional UCiT. Following assembly, a tablet computer with a rear-facing camera was positioned on the UCiT; once turned on, the camera application on the tablet readily displayed the UCiT's surgical training field under ambient lighting (Fig. 2).

UCiT Dissemination and Evaluation

Four international academic institutions (University of Rome, Tor Vergata, Rome, Italy, University of Modena and Reggio Emilia, Modena, Italy, Smith Institute for Urology — Northwell Health System, New Hyde Park, New York, and Asian Hospital and Medical Center, Manila, Philippines) were selected to participate in this study. Two of these institutions were sent a Flashforge Creator 3D printer ($876.00 USD, Zhejiang Flashforge 3D Technology Co., Jinhua, China) with CAD files and were required to set up the 3D printer, while the other two institutions were sent the 3D-printed UCiT parts. All 4 sites were sent UCiT assembly instructions and several nonprinted UCiT components along with questionnaires assessing: the 3D-printing process (2 sites), ease of assembly of the UCiT (Appendix 1), UCiT functionality, and overall quality of the UCiT device (Appendix 2). Also, at each institution, the trainees completed basic laparoscopic tasks (ie, knot-tying and peg transfer) on the UCiT; they were also expected to complete the same tasks on their institution's standard laparoscopic trainer (Karl Storz Inc., Germany or Richard Wolf Inc., IL). For both devices, the trainees were evaluated during the simulation session by a designated faculty member using the Objective Structured Assessment of Technical Skill (OSATS), a validated assessment tool for surgical trainees.[3]

Set-up and Evaluation: All trainees were given a standardized explanation of the 2 tasks to be completed during the study. The camera for both trainers was in a fixed position. Standardized peg boards and suture blocks were provided to each institution

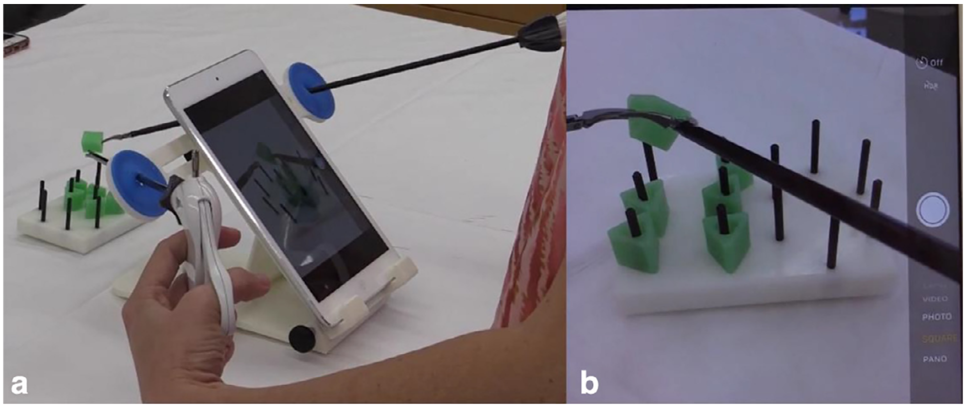

Figure 2. (a) Full assembled UCi Trainer with instruments and an iPad, (b) iPad view. (Color version available online.)

Table 1. Objective structured assessment of technical skills

	Peg Transfer (n = 16)		
	UCiT	Standard	*P Value*
Mean skills assessment (Max score 48)	36	37	.649
Mean time (sec)	164	154	.721
	Intracorporeal Knot Tying (n = 16)		
	UCiT	Standard	*P Value*
Mean procedure specific (Max score 16)	12	12	.834
Mean global rating scale (Max score 20)	13	14	.740
Mean time (sec)	436	382	.359

and were placed directly at the center of the camera image. The iPad effectively blocked the view of the working field, and the study participants were specifically instructed to not look over the iPad, which was also monitored by the proctors. The starting order of trainers (UCiT or standard trainer) for each participant was computer randomized, and each trainer was used only once to complete the task. Upon completion of both tasks, each trainee answered a Likert-type questionnaire regarding various aspects of each trainer (Appendix 3).

Statistical differences were assessed using Mann Whitney U and *t* tests and significance was set at $P < .05$.

RESULTS

A total of 25 individuals participated in this study from the 4 institutions; 20 (80%) of the participants were residents at various levels of training and 4 were practicing urologists. Four individuals, 2 first-year residents, 1 fourth-year resident, and 1 fifth-year resident, tasked with 3D printer set up rated UCiT as difficult to use and set up (1.25/5; scale = 1 being very difficult to 5 being very easy). Of those 4 participants, 2 took less than 30 minutes to set up the 3D printer out of the box to begin printing the UCiT, and 2 took less than 3 hours. Eight participants were selected to assemble the UCiT at their respective institution; 6 successfully assembled UCiT independently while 2 participants required additional assistance provided through email and oral instructions from the study investigators. UCiT assembly was rated as somewhat easy (3.5/5; scale = 1 being very difficult to 5 being very easy); however, 5 participants assembled the UCiT in less than 15 minutes while the remaining 3 participants assembled the UCiT in less than 45 minutes. The cost of the printed and nonprinted materials required to assemble each UCiT was $26.50 USD (not inclusive of the printer). In all cases, a second-generation Apple iPad (Apple, Cupertino, CA) was used for the UCiT optics.

On objective testing of tasks using the OSATS scoring system, there were no significant performance differences for tasks performed on the UCiT trainer vs the conventional laparoscopic trainer for either peg transfer or intracorporeal knot-tying (Table 1). However, when the participants rated device quality and their ability to perform the tasks, the scores for image display quality, display lag, device comfort, and overall performance were significantly higher for the conventional laparoscopic trainer vs the UCiT (3 vs 4, 3 vs 5, 3 vs 4, 3 vs 4, $P < .05$, respectively) (Table 2).

Among the study subjects, 48% reported that the UCiT was similar to the operative room laparoscopic experience, 44% indicated the UCiT was comfortable to use, 88% noted that working with the UCiT was good for practicing skills, 64% would purchase the UCiT, and 80% would recommend the UCiT for resident training. Of note, while the participants preferred the standard laparoscopic trainer over the UCiT; the majority of participants (64%) did not practice laparoscopic skills outside the operating room (OR) citing that they had no time (50%), no access to training devices (43%), or did not do laparoscopy (7%).

Table 2. Subjective rating questionnaire

	UCiT (n = 25)	Standard (n = 25)	*P Value*
Image quality	3 (2-5)	4 (3-5)	.0017
Display lag	3 (1-5)	5 (3-5)	<.001
Comfort	3 (1-5)	4 (3-5)	.0028
Overall performance	3 (2-5)	4 (3-5)	.002

DISCUSSION

With the advent of laparoscopy and laparoscopic robotic surgery, the model for surgical training has shifted from the traditional operating room experience and Dr. William Halsted's mantra of "see one, do one, teach one" to a more systematic approach of teaching by learning skills, tasks, and procedures in a surgical laboratory or other non-OR environment.[2] For standard laparoscopy, there is a steep learning curve due to counterintuitive movements, the indirect view of the surgical field and the lack of depth perception caused by the 2D camera view.[2,6] As such, early laparoscopic skills are focused on learning to move the instruments efficiently and effectively. Using a simulator, a novice can master standardized skills and subsequently tasks outside of the operating room. Surgical trainees view simulators as a beneficial adjunct to their training and note that the skills/tasks mastered in this fashion transfer into the operating room.[7] Indeed, multiple studies documented improved performance, reduced operative time and errors with the use of simulation training.[8-12] However, despite the widespread availability of simulators in surgical training facilities, they go underutilized.[13] Clements and colleagues reported that the majority of urologists in the United States have access to simulators, but fail to use them.[14] This lack of training outside the operating room becomes a more pressing problem given the last decade of duty hour limItations.[15]

In our study, consistent with the cited literature, 64% of the participants did not practice laparoscopic skills outside of the operating room. They reported either not having enough time (50%) or the equipment not being available (43%). The UCiT addresses these issues by providing a compact, portable, and easily assembled training device. Of note, a single institution that received a brand new disassembled 3D printer found it difficult (1.25/5) to assemble and set up. This in turn created difficulty in printing the 3D UCiT parts correctly as some of the pieces did not fit well together. This was also the only institution to rate the UCiT assembly as difficult; however, the overall assembly of the pieces and initial usage of the UCiT was relatively easy (3.5/5). Nonetheless, in all cases the printing, assembly, and first usage were always accomplished in <3 hours. For the future, it is essential to have the 3D printer optimized prior to printing the specific components.

The UCiT overcomes the deterrents to laparoscopic training due to UCiT's low cost, easy assembly, and storage, and UCiT's 24/7 availabilIty.[7,16,17] The UCiT empowers residents to train in a setting of their choosing whether UCiT be at work or at home. Other low-cost, novel laparoscopic trainers have also been developed; however, the UCiT device is unique as it could be printed and assembled in four distinct geographical areas (Manila, Philippines, Rome, Italy, Modena, Italy and New Hyde Park, NY, USA).[17] Furthermore, the cost of the materials required to assemble a functional UCiT is marginal ($26.50 USD). However, if the department does not possess a basic entry level 3D printer, the files are in standardized file format (stereolithography, STL) and any 3D printer with a minimum printing bed of 8 × 5 inches (over 90% of 3D printers on the market meet this requirement) could be used. At different universities the cost for the 3D printed materials ranged from $30 to $80 USD; which is far less expensive than currently available laparoscopic trainers used for the FLS system, the purchase price of which online ranged from $1164 to $6510 USD.[4] Le and colleagues have indicated that urology residency program directors throughout the United States recognized the role for simulation training, however its incorporation into the curriculum had yet to be determined.[16] Given the ease of dissemination and use of the UCiT device, it could easily be incorporated into a residency program at a low cost with minimal effort and faculty oversight.

Residents performed similarly for both the peg-transfer and intracorporeal knot tying based on the OSATS scoring system using either the UCiT or traditional laparoscopy trainer. Although only 48% of participants indicated that the UCiT simulator was akin to the operative room laparoscopic experience, 88% noted that the UCiT provided a good practice format and would recommend the UCiT to their colleagues (80%). Further, 64% of the participants would purchase for the UCiT device for personal use. A study by Supe and colleagues underscores the importance of a low-cost laparoscopic trainer.[18] They investigated skill retention of the traditional observe and assist laparoscopy training alone vs the addition of low-cost laparoscopic trainers as an adjunct. The residents were tested at day one and then 5 months after performing the global operative assessment of laparoscopic skills (GOALS) rating scale. They found that there was significant skill retention with the addition of laparoscopic trainer.

In contrast to the aforementioned similarities, the subjective scoring of image quality, display lag, comfort, and overall performance was rated significantly better with the traditional trainer. We believe using a tablet with a rear-centered camera such as the 8-inch Samsung Galaxy would improve overall performance and updates to the Solidworks software could improve the video lag and image quality. Furthermore, to enhance comfort, the height of the UCiT could be adjusted to achieve the most ergonomic position for the surgeon; unfortunately this was not done routinely in the present study.

The major drawback of our study was the small and diverse group of residents and faculty, both with varying laparoscopic experience. Additionally, the CAD files required for 3D printing were sent to the institutions whereas in the future we would utilize an open source website for large-scale dissemination with one click ordering of a package of the nonprinted UCiT components. Also, the simulation was not video recorded and the objective scoring using the OSATS scoring system was done only once by a single designated proctor. An open source website where users can obtain CAD designs and a small package of materials will be available for large-scale dissemination in the future. Finally, we did not include the cost of the tablet used with the UCiT, the cost of the laparoscopic instruments or the 3D printer during the study.

CONCLUSION

We have developed a low-cost ($26.50 USD) 3D printed alternative to the standard laparoscopic trainer. The UCiT is easily portable, and once printed it can be assembled in less than 45 minutes. Despite a preference for the standard trainer, the participants in this study performed equally well on both the UCiT and the traditional laparoscopic trainer and the majority would purchase UCiT as well as recommend UCiT to their colleagues.

SUPPLEMENTARY MATERIALS

Supplementary material associated with this article can be found, in the online version, at https://doi.org/10.1016/j.urology.2018.06.034.

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