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Development of a knowledge, skills, and attitudes framework for training in laparoscopic cholecystectomy

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Abstract

BACKGROUND: The implementation of duty-hour restrictions and a heightened awareness of patient safety has changed resident education and training. A new focus has been placed on high-yield training programs and simulation training has naturally grown to fill this need.

METHODS: This article discusses the development of a training framework, knowledge, skills, and attitudes, and the design of a surgical simulation curriculum. Five residents were recruited for a pilot study of the curriculum.

RESULTS: A successful framework for curriculum development was implemented using laparoscopic cholecystectomy as the example. The curriculum consisted of classroom and virtual reality simulation training and was completed in 3.1 to 4.8 hours.

CONCLUSIONS: The current curricula that have been developed for surgical education cover the breadth of a surgical residency well. This curriculum went beyond these curricula and developed a structured framework for surgical training, a method that can be applied to any procedure.

Educational strategies are continuously evolving, especially in surgical education. With the implementation of duty-hour restrictions, a push for more cost-effective medicine, and a heightened awareness of medical errors and patient safety, training has shifted from the operating room and wards to other learning environments. The optimal training environment and learning strategy have been the focus of much discussion and debate.[1,2] Simulation has been one solution, providing the opportunity for a safe learning environment that is both immersive and experiential. Multiple studies have assessed the efficacy of simulation training and have shown that surgeons who are trained using simulation show improved technical skills in the operating room.[3–5]

So far, there has been an intense focus on technical skills training; however, focus has recently shifted to include training in nontechnical and teamwork skills.[6] Nontechnical skills are the interpersonal and cognitive skills that complement technical skills and are essential to safety in the operating room. Examples include situational awareness, communication, decision-making, and teamwork.[7]

Although simulation offers a very promising training modality for novice surgeons, simulators and simulation laboratories alone are not enough to institute a training program. Fully developed curricula, ideally based on evidence, are required. To this end, there have been multiple solutions suggested for training surgical residents, including the Surgical Council on Resident Education, the Surgical Education and Self-Assessment Program, and Fundamentals of Laparoscopic Surgery (FLS) curricula, as well as the American College of Surgeons (ACS)/Association of Program Directors in Surgery (APDS) skills curriculum. The Surgical Council on Resident Education is a comprehensive list of the topics to be covered in surgical resident education focusing on knowledge and procedures. This standardizes the training goals and ensures that each resident has been exposed to a set of tasks and has a certain set of competencies when graduating. The ACS produced the Surgical Education and Self-Assessment Program that also focuses on clinical knowledge and test preparation with a collection of problem-based multiple-choice questions. Many simulation curricula in residency programs in the United States consist in part of the FLS certification. It is a standardized training and testing system that consists of web-based learning modules as well as training and assessment in a laparoscopic box trainer.[8] The ACS and APDS developed a standardized 3-phase surgical skills curriculum that advances from basic surgical skills to advanced procedures and then team-based skills.[9] The training is done using the FLS modules, video trainers, and finally a virtual operating room with team-based exercises. The ACS/APDS skills curriculum is unique in that it incorporates nontechnical skills training. This component is often overlooked in simulation curricula because of the difficulty in including it, but just like technical skills, can be improved with training.[10]

An important part to these curricula (and any other successful curriculum) is the ability to assess residents' progress and develop benchmarks and passing points for training. Both the FLS and ACS/APDS skills curriculum incorporate assessment into the training. In this article, we present a modular approach to the design of a surgical simulation curriculum, including a framework for the assessment of residents' competence. We present the development of the curriculum and assessment framework in detail and we report data on the feasibility of the delivery, including resources required (time, manpower, and equipment) and time taken to complete the curriculum. We use laparoscopic cholecystectomy as an example of a procedure-specific curriculum because it is one of the first procedures that surgical residents perform–the curriculum and framework, however, can be applied to any procedure.

Methods

The goal of this framework was to approach surgical education in a way that is similar to real life, through gaining knowledge, skills, attitudes, and behaviors. A surgeon first develops the knowledge base for the disease and treatment, and then continues to build on the knowledge base as he/she practices the technical intricacies of the procedure. Throughout this time, nontechnical and team skills also develop. Typically, nontechnical skills are not formally taught, rather surgeons are trained in an informal and unstructured manner, with trainees observing the practices of experienced and respected colleagues for guidance on how to behave and interact with other members of the operating team. In the development of this framework, we draw upon the wide literature that incorporates not only technical skills but also knowledge, attitudes, and teamwork.[11,12] These elements are also the 3 core components that are evaluated by Kirkpatrick in his seminal work of evaluating training.[13]

An example of using this framework to develop a laparoscopic cholecystectomy curriculum is discussed here. It is based on previously validated components as well as new interactive media components. The intended audience was surgical residents early in their career, before they had completed 25 laparoscopic surgeries. Because laparoscopic cholecystectomies are frequently seen in surgical practice and are one of the first procedures done by trainees, the surgical curriculum focused on laparoscopic cholecystectomies. Five surgical trainees were recruited to pilot the training curriculum. Informed consent was obtained from the residents and approval was obtained from the Ethics Review Board at Imperial College London.

The 3 core elements of the curriculum and framework were designed as follows:

Knowledge

This portion was based on the Laparoscopic Cholecystectomy Course Handbook and video from the Royal College of Surgeons (UK)[14] introducing the trainee to the equipment and theory of laparoscopic surgery. The video discusses the basics of laparoscopy, how to perform a laparoscopic cholecystectomy, and how to use the simulator. In more detail, it involved the following:

1. Background: Brief history of laparoscopic surgery
2. Fundamental skills: Description of the 2-dimensional nature of laparoscopic surgery as well as using tools with fulcrum points
3. Error training: Description of a laparoscopic cholecystectomy, the different steps involved, and the common pitfalls of the procedure.
4. Introduction to a new environment: Demonstration of the LAP Mentor cholecystectomy, how to change the surgical tools and how to use the simulator
5. Consolidation: A complete narrated simulated surgery done by a senior consultant.

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Technical skills

Technical skills are the mainstay of surgical education and can be taught in many different ways from practicing knot tying on a board to box trainers, animal models, and full surgical procedures using virtual reality simulators. A simulator allows for an objective, structured training environment that both trains and assesses the student. The technical skills portion of the curriculum was completed on the LAP Mentor (Gothenburg, Sweden), a virtual reality simulator with haptic feedback. The surgeon interacts with the simulator through 2 haptic feedback instruments. The type of tool that the instrument represents (clipper, grasper, cautery, etc) can be changed on the screen. The simulator allows for a safe and comfortable environment where surgeons can make mistakes and practice their skills at their own pace. It also allows for objective measures of surgical performance. An example of a student using the LAP Mentor simulator is seen in Fig. 1.

For this component of the training, we used a validated, step-wise, proficiency-based virtual reality training curriculum developed at our institution.[15] Initially, trainees complete basic, nonsurgical tasks such as moving different shapes into holes or clipping leaking hoses. When these tasks are completed to predefined levels, the trainee moves on to complete components of a laparoscopic cholecystectomy such as retracting the gallbladder or separating it from the liver bed. These too have predefined passing criteria that are met as the trainee practices and fine-tunes different portions of the procedure. The simulation culminates in a

full laparoscopic cholecystectomy that the trainee also has to complete within a set of predetermined criteria. The criteria for passing each step and moving on to the next task were based on the levels achieved by experts as compared to novices and intermediate surgeons when completing the tasks. Each level uses a combination of simulator-collected data such as time, hand movements, and accuracy of cautery to define the passing levels. The tasks need to be performed on different days with an hour of rest in between each set of procedures. This was done so that the surgeon remembers the tasks over time and does not complete them rapidly one after another. The assessment points used include time taken, number of hand movement, accuracy, and path length. Fig. 2 describes the curriculum.

The training is completed at the trainee's leisure with flexibility to allow for a resident's busy schedule. Because this is a proficiency-based curriculum, the trainees require varying amounts of time to complete the simulation training.

Attitudes and behaviors

The third and final portion of the curriculum consisted of team attitudes and behavior training. This training complements the technical skills portion of the training with the nontechnical skills that a surgeon needs to be successful in the operating room. This can also be taught in many ways from lectures to virtual world avatars and full-team simulations. The costs and time commitment of full-team simulations are prohibitive for many centers and therefore a modified interactive video was designed. This was based on the TeamSTEPPS Fundamentals Course.[16]

TeamSTEPPS is a teamwork system for health professionals designed by the U.S. Department of Defense's Patient Safety Program and the Agency for Healthcare and Quality. We used the fundamental modules of this tool and combined it with our own video vignettes to show key concepts. The TeamSTEPPS fundamental course discusses leadership, situational monitoring, mutual support, and communication.

The video vignettes were developed for the purposes of this project. They were a set of surgical cases designed by a team of surgeons and psychologists at our institution to portray teamwork situations in the operating room that needed improvement. The videos were designed using 6 evidence-based areas of nontechnical skills: communication, coordination, cooperation/backup behaviors, leadership, and situational awareness (see the behaviors assessed by the well-validated Observational Teamwork Assessment for Surgery instrument below). These situations were played out by actors in the simulated operating room and recorded. The video vignettes were combined with the TeamSTEPPS modules to form a 30-min video. Fig. 3 shows an image captured from the video vignette in the operating room.
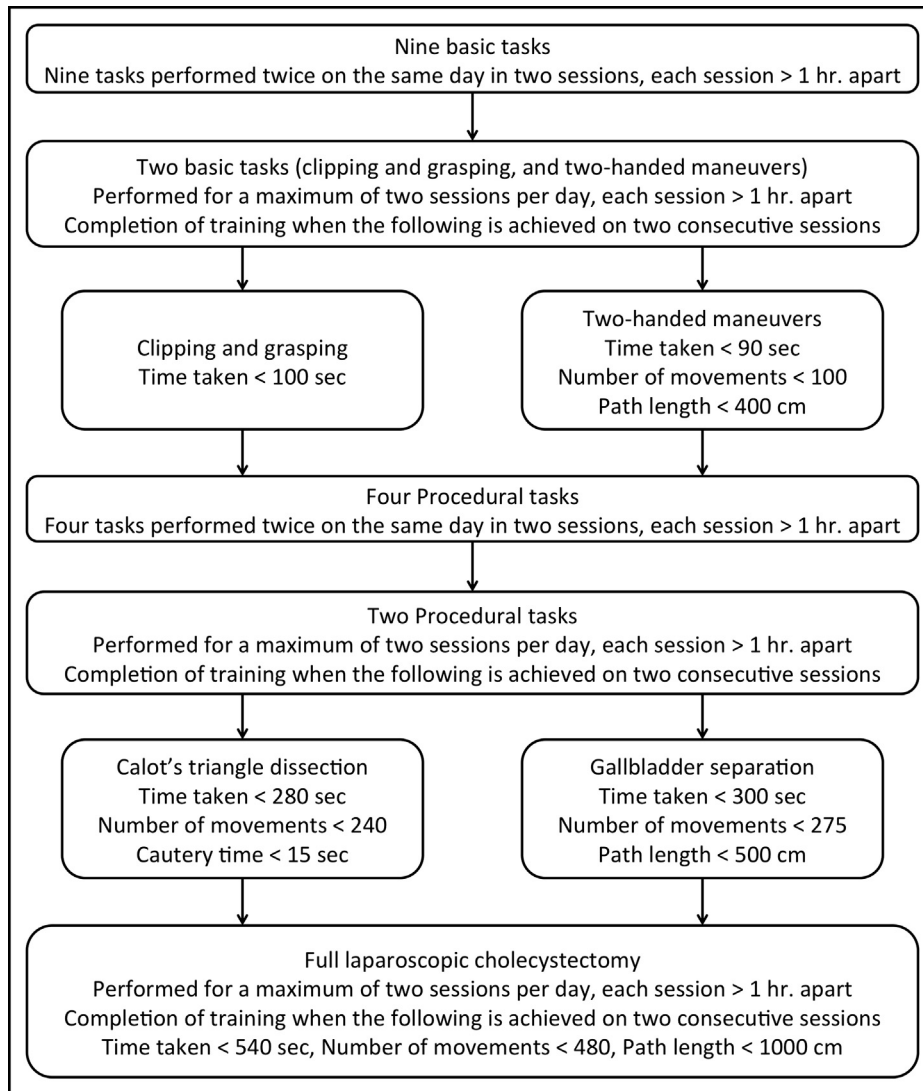

Figure 1   Student using the LAP Mentor simulator.

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┌─────────────────────────────────────────────────────────────────┐
│  Nine basic tasks                                                 │
│  Nine tasks performed twice on the same day in two sessions,      │
│  each session > 1 hr. apart                                       │
└─────────────────────────────────────────────────────────────────┘
                              ↓
┌─────────────────────────────────────────────────────────────────┐
│  Two basic tasks (clipping and grasping, and two-handed maneuvers)│
│  Performed for a maximum of two sessions per day, each session    │
│  > 1 hr. apart                                                    │
│  Completion of training when the following is achieved on two     │
│  consecutive sessions                                             │
└─────────────────────────────────────────────────────────────────┘
        ↓                                        ↓
┌──────────────────────┐              ┌──────────────────────────┐
│  Clipping and grasping│             │  Two-handed maneuvers     │
│  Time taken < 100 sec │             │  Time taken < 90 sec      │
│                       │             │  Number of movements < 100│
│                       │             │  Path length < 400 cm     │
└──────────────────────┘              └──────────────────────────┘
        ↓
┌─────────────────────────────────────────────────────────────────┐
│  Four Procedural tasks                                            │
│  Four tasks performed twice on the same day in two sessions,      │
│  each session > 1 hr. apart                                       │
└─────────────────────────────────────────────────────────────────┘
                              ↓
┌─────────────────────────────────────────────────────────────────┐
│  Two Procedural tasks                                             │
│  Performed for a maximum of two sessions per day, each session    │
│  > 1 hr. apart                                                    │
│  Completion of training when the following is achieved on two     │
│  consecutive sessions                                             │
└─────────────────────────────────────────────────────────────────┘
        ↓                                        ↓
┌──────────────────────────┐          ┌──────────────────────────┐
│  Calot's triangle         │         │  Gallbladder separation   │
│  dissection               │         │  Time taken < 300 sec     │
│  Time taken < 280 sec     │         │  Number of movements < 275│
│  Number of movements < 240│         │  Path length < 500 cm     │
│  Cautery time < 15 sec    │         │                           │
└──────────────────────────┘          └──────────────────────────┘
        ↓
┌─────────────────────────────────────────────────────────────────┐
│  Full laparoscopic cholecystectomy                                │
│  Performed for a maximum of two sessions per day, each session    │
│  > 1 hr. apart                                                    │
│  Completion of training when the following is achieved on two     │
│  consecutive sessions                                             │
│  Time taken < 540 sec, Number of movements < 480, Path length     │
│  < 1000 cm                                                        │
└─────────────────────────────────────────────────────────────────┘
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Figure 2   Diagram of virtual reality training curriculum for laparoscopic cholecystectomy, showing the progression from basic tasks to a full cholecystectomy.[15]

The trainees watched the video and after each vignette they were prompted to reflect on what they saw. The discussion that followed was based on the components of surgical teamwork as defined by the Observational Teamwork Assessment for Surgery (OTAS). OTAS was designed to measure inter-professional teamwork in the operating room. OTAS assesses 5 teamwork behaviors: communication, cooperation/backup behavior, leadership,

Figure 3   Video vignette of teamwork in the operating room.

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coordination, and team monitoring/situational awareness.[17] OTAS consists of a number of "exemplar behaviors" that indicate exemplary teamwork and are associated with effective, safe surgical practice that a trained rater uses to assess the quality of teamwork of surgeons, anesthesiologists, and nurses in the operating room.[18] We used the grading scale as a framework to define best practices in the operating room such as "the surgeon informs the team of technical difficulties or changes in patient requirements."

Trainees were instructed to analyze how the simulated team handled issues in communication, coordination, cooperation/backup behaviors, leadership, and team monitoring/situational awareness using the OTAS framework. They were then asked to discuss what aspects of the videos they thought could be improved and what they would like to incorporate into their own practice.

Results

Five surgical residents completed the curriculum as a pilot program to test the feasibility of delivery and to identify any potential issues and areas for improvement within the curriculum.

Feasibility of delivery and trainee reactions

The trainees completed the knowledge portion in 18 min without any reported problems. The description of how the simulator worked was not detailed enough and each trainee needed additional one-on-one teaching of the simulator to be able to use it. The mean total time needed to complete the simulation curriculum was 2 hours 47 min (range of 2 hours 12 min to 3 hours 51 min) spread over 6 to 11 days. Because some trainees had to repeat the basic skills up to 15 times, they were allowed to do 4 sessions per day with a break in between. The time taken and number of attempts needed is seen in Fig. 4. During these sessions, an assistant, well versed in simulator training, was present to assist trainees with the simulator. After the initial session, the

trainees did not request help from the assistant and the curriculum could be completed without assistance.

The attitudes and behaviors portion of the training included a video that lasted 31 min and a structured discussion about the key teamwork concepts portrayed in the video vignettes, which lasted for 5 to 15 min. A facilitator was present during the discussion (but not during the time the video was being watched). During the facilitated discussion of the video vignettes, the trainees were asked to identify any improvements in the teamwork or any positive aspects of the behaviors of the team members. These observations are seen in Fig. 5.

The resources needed to develop the knowledge portion of the curriculum were minimal. The video introduction to laparoscopic surgery is available through the Royal College of Surgeons,[14] and the additional simulator and procedure-specific components took 2 hours to develop, resulting in 9 min of film.

For the simulation-based part of the course, the resources and costs included the LAP Mentor simulator, which was not used exclusively for this research, and the time of an assistant, approximately 30 min per trainee. To develop a new technical skills curriculum, an estimated 45 hours of faculty time, 31 hours of resident time, and 84 hours of medical student or intern time would be needed. This is estimated from the original development of the validated curriculum, recruiting 57 subjects: 16 experienced, 11 intermediate, and 30 inexperienced operators,[15] multiplied by the time taken by the pilot study trainees, a mean of 2 hours 47 min.

For the attitude and behavior part of the course, the video was designed over the course of 10 hours by a surgeon and psychologist and then recorded in a simulator suite using 6 actors for 2 hours, the voice over and editing was done by the authors requiring an additional 2 hours, for a total of 34 man-hours.

The estimated cost associated with the development of the curriculum is mostly in labor, approximately 36 hours which includes a 2-hour block of time in the simulator suite. The costs of running the program include the simulator, and an hour of an assistant's time per trainee.
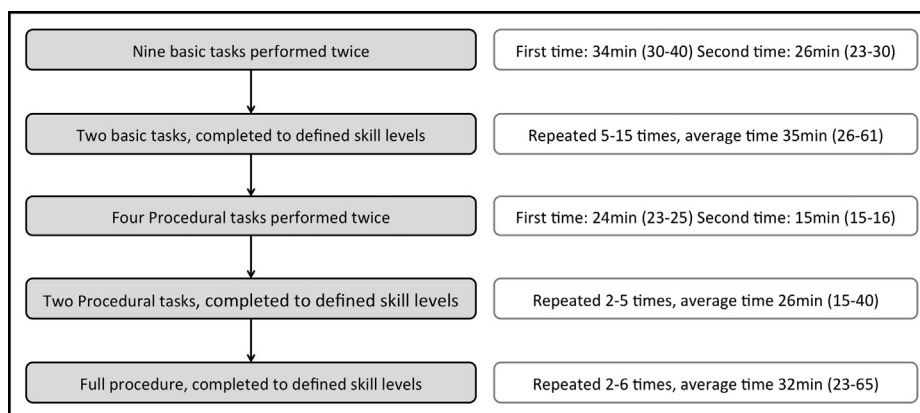

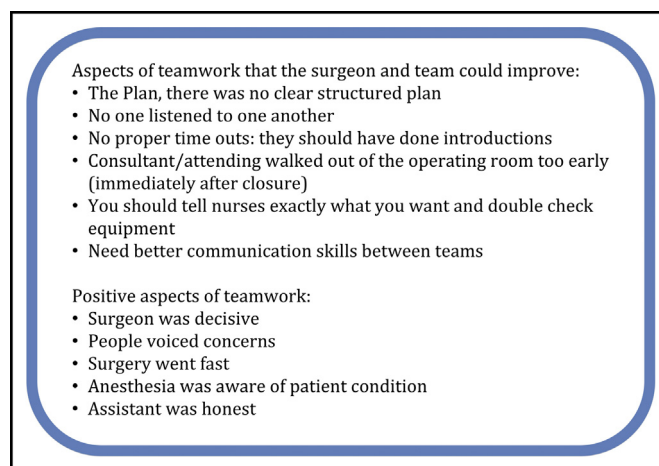**Figure 4**   Time to completion of each step of LAP Mentor curriculum.

Figure 5   Positive and negative aspects of teamwork noted by trainees.

In addition to this, if the technical skills and simulator curriculum had not already been developed, we estimate that an additional 160 hours of faculty, resident, medical student, and simulator time would be needed.

Comments

Existing curricula that have been developed for surgical education cover the breadth of a surgical residency well. The intention of this curriculum was to go beyond these curricula and develop a framework for surgical training: a method that can be applied to any procedure. For example, to expand upon this curriculum the knowledge section could be replaced with specifics for the chosen surgical procedure, with a set of hints and tips from senior surgeons. This introductory knowledge is important as a base to build upon during the rest of the training. Compiling experts' knowledge and suggestions gives residents a compressed version of some components that are taught in the operating room. The technical skills curriculum was based on a set of simulation modules that are a part of the LAP Mentor simulator. There are other procedures as well that have been developed for the LAP Mentor simulator and more are being added yearly.[19] The passing criteria were based on expert surgeons' levels during those modules, which could be done for any new curriculum or procedure.

The novel part of this curriculum is the teamwork and attitudes section. As mentioned, the cost of a full virtual operating room or team simulations can be prohibitive, and this form of delivery may be a particularly useful training modality before encountering full-team simulation, considering the level of residents recruited in this study. This curriculum made up for the lack of an immersive experience with videos and discussion sessions so that the surgeons truly thought about what was being shown. The video with these main principles of teamwork is not procedure specific and could be used for other procedural training as well.

In this specific case example, the 5 trainees who piloted the curriculum were able to complete it with varying speed. In total, it took 3.1 to 4.8 hours to complete the curriculum spread over 6 to 11 nonconsecutive days. The most difficult part of the training was finding time for the surgeons to complete it. Building structured technical and nontechnical skills time into the training program could alleviate this. The trainees enjoyed learning new materials and skills and learned how to use the simulator quickly.

We developed this curriculum over a total of 36 hours, of which 2 hours were spent in a simulated operating room and another hour on the simulator. If an institution already has a training facility with a simulator, the additional time to develop a specific procedure curriculum is not prohibitive. Once the curriculum is developed, only 1 hour per trainee is needed for the introduction, and basic teamwork attitudes training, such as the type of training we report here. We used a previously validated curriculum for the technical skills training; if this had to be developed for a new procedure, an estimated 76 hours of faculty and resident time would have to be spent on a simulator.

The benefit of a modular approach to surgical training is that parts of the curriculum can be used for different procedures, making new curriculum development less costly. This approach to curriculum development reduces the barrier to new development. Using a modified version of this curriculum will take time, for example, validating a new technical skills curriculum, but it is more feasible than creating a completely new curriculum. Developing the faculty to create and run the curriculum, if not already present at an institution, will of course also take time and resources. Because of the modular nature of this curriculum, the implementation of the different components has some flexibility. For example, the knowledge section can be viewed by the trainees from their computers when they have down time and the attitudes and behavior discussions could be done in lecture format or small group discussions to minimize faculty time requirements and cost. The simulator is also a costly component of the training

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program; the technical skills component could be replaced with training on a different, less costly, simulator.

Some limitations of this work are that the nontechnical skills or attitudes were not taught and developed to the same degree as the technical skills component. The learning was accomplished in a more passive manner, and did not include simulation work. Further research is needed to determine the level of simulation that is most cost-effective at different levels of training. This pilot evaluation was developed to assess the feasibility of trainees using this curriculum, but no wider scale implementation (eg, across an entire residency program) was attempted, nor longer term follow-up of the trainees was feasible to carry out. In further evaluation of this curriculum, the trainees' reactions to the curriculum should be formally recorded as well as the change in their knowledge and attitudes and retention over time. Finally, the clinical implication of this training should be shown in the operating room.

This curriculum design and pilot study showed that smaller-scale, procedure-specific training curricula can be designed on an institutional level and can be implemented within an academic surgical center. The main concern for the success of such curricula is the time the residents are given to complete the curriculum which may take them away from their patient duties. With a shifting emphasis to high-yield structured training outside of the operating room, there should now be space for this type of training. Further work includes larger implementation of the knowledge, skills and attitudes framework to assess real-world outcomes of this curriculum design.

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