

Maintaining technical proficiency in senior surgical fellows during the COVID-19 pandemic through virtual teaching



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ABSTRACT

Background: The novel coronavirus (COVID-19) pandemic has resulted in a severe reduction in operative opportunities for trainees. We hypothesized that augmenting independent practice with a bench model of vascular anastomoses using regular videoconferences and individual feedback would provide a meaningful benefit in the maintenance of technical skills in senior lung transplant surgical fellows.

Methods: A lung transplantation virtual technical skills course was developed, and surgical fellows were provided with a bench model and surgical instruments. Using a virtual communication platform, teaching sessions were held twice weekly, and fellows performed an anastomosis on camera. Video recordings were reviewed and critiqued by attending staff. At the end of the 3-month course, participants were surveyed about their experience. Warm ischemic time was compared between the fellows' 5 most recent cases before and after the pandemic.

Results: Seven senior surgical fellows participated and provided feedback. The fellows had graduated medical school an average of 14 years before fellowship, and spent an average of 5 hours (range, 1.3-15 hours) of home practice. Five of the 7 participants (71%) reported improvement in their technical skills and increased confidence in performing lung transplantation. No significant difference in average warm ischemic time in procedures performed by fellows was identified (70.3 minutes pre-pandemic vs 68.3 minutes post-pandemic; $P = .68$).

Conclusions: A program of virtual technical skills teaching, individual video coaching, and independent practice has provided a benefit in maintaining technical skills in lung transplant surgical fellows during the COVID-19 pandemic, when equivalent operative experience was unavailable. Lessons learned from this exceptional time can be used to create simulation curricula for senior trainees. (JTCVS Open 2021;8:679-87)



A bench model provided to lung transplant fellows to take home and practice technical skills in lung transplantation, demonstrating pulmonary artery and atrial anastomoses. This model has provided a platform for video-based virtual teaching sessions during the COVID-19 pandemic.

CENTRAL MESSAGE

The limitations imposed by the COVID-19 pandemic have allowed for the creation of a novel and effective format of teaching technical skills for senior learners, a model for future curriculum development.

PERSPECTIVE

The COVID-19 pandemic has significantly impacted surgical training but yet has provided an opportunity to develop an innovative method of teaching technical skills. This program, specifically adapted for senior learners, includes virtual technical skills teaching with a novel bench model and live-time video coaching, and provides a framework for the development of future virtual technical skills curricula.

See Commentaries on pages 688 and 690.

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Abbreviations and Acronyms

COVID-19 = Novel coronavirus
OR = Operating room

▶ Video clip is available online.

The novel coronavirus (COVID-19) pandemic has resulted in a severe reduction in operative opportunities for lung transplant surgical fellows. The Toronto Lung Transplant Program suspended transplantation activity for several months, with only a few exceptions for highly selected, rapidly deteriorating patients. Concerns about deskilling in technical abilities with an extended break from operating has been described previously,¹⁻³ with fellows in the early stages of learning an operation particularly vulnerable. Academic faculty in our institution consider senior postgraduate learners to have different educational requirements than undergraduate students and residents, with most having extensive surgical experience in general surgery, thoracic surgery or cardiac surgery.

The ultimate goal of simulation is to improve patient outcomes, but this has been very difficult to prove.⁴ The goal is for trainees to acquire skills in the simulation lab that can then transfer to the operating room (OR), yet much work remains to demonstrate that this skills transfer actually occurs. There have been some studies examining skill transfer using various simulation models in different surgical subspecialties; however, there remains a paucity of data on the success of skills transfer from a simulation model to the OR for senior trainees.⁵⁻⁷ In fact, there is a paucity of studies in the literature focusing on simulation training for senior trainees, with most such studies focused on junior learners (ie, junior residents and medical students). With respect to junior learners specifically in cardiothoracic surgery, there is an increasing evidence indicating that low-fidelity simulation, including unsupervised practice on a bench model,⁸ improves performance, with a time-constrained training curriculum, faculty supervision, and a model of friendly competition being potentially useful adjuncts.⁹

We hypothesized that augmenting independent practice with a bench model of pulmonary vascular anastomosis with regular videoconferences and individual feedback would have benefits in terms of acquisition or maintenance of technical skills in lung transplant surgical fellows. We also hypothesized that the techniques developed during this imposed slowdown may be used in the education of senior trainees going forward, including virtual technical skills teaching, practice at home, personalized coaching and advice, and group discussion and feedback.

METHODS**Technical Skills Course**

An industry partner with a commitment to education of surgeons (Scanlan International, St Paul, MN, USA) provided and delivered surgical instrument sets to each fellow's home address. The model was initially developed for and used in our annual national simulation-based surgical skills bootcamp in thoracic surgery, and the equipment and supplies included a long-shafted Castroviejo needle driver, forceps, a novel stand with clips to mount the simulated tissue, rubber balloon (to simulate thin-walled pulmonary artery) and multiple packets of 5-0 Prolene sutures (Figure 1).¹⁰ A total of 7 fellows were provided with this bench model for home use. The fellowship program director provided instructions on how to use the model and set up the anastomoses. The intention of the course was to allow fellows to practice anastomoses of the vascular structures (ie, pulmonary artery and left atrium) of a lung transplantation operation. Figure 2 shows a completed anastomosis on the bench model of a simulated pulmonary artery and left atrial cuff. Anastomosis of the left atrium can be particularly challenging, and we routinely use an everting mattress suture technique to minimize complications.¹¹ Initially, fellows were required to practice at home and perform the anastomosis with timed testing. Improvement in surgical efficiency was usually noted (Video 1). Once the fellows gained familiarity with the model, they were asked to create a video recording of an attempt using a mobile telephone.

Various clinical technical scenarios encountered during lung transplantation surgery were simulated, including challenges with donor-recipient vessel size mismatch, short vessel cuffs, and specific suture methods for the left atrial cuff anastomosis (Figure 3). Specific teaching was provided to trainees on how to manage these scenarios, and most fellows had encountered at least one of these situations in their clinical experience. Using a virtual communication platform (Microsoft Teams), teaching sessions were held twice weekly, with the first meeting to introduce the concept of virtual technical skills teaching and demonstrate the model. During each biweekly video conference, volunteer fellows would perform an anastomosis on camera while attending staff commented on their technique and provided advice in real time to deal with specific difficulties that the trainee might encounter.

Finally, each fellow recorded an attempt at the anastomosis using a mobile phone. The videos were sent to the staff surgeon, who provided a private critique of the fellow's performance, advice on errors and hesitations, and suggestions for improvement. With permission from the trainee, these videos were also shared virtually at the teleconference sessions for group



FIGURE 1. Equipment and supplies for the bench model provided to lung transplant surgical fellows for independent home practice and virtual skills teaching.

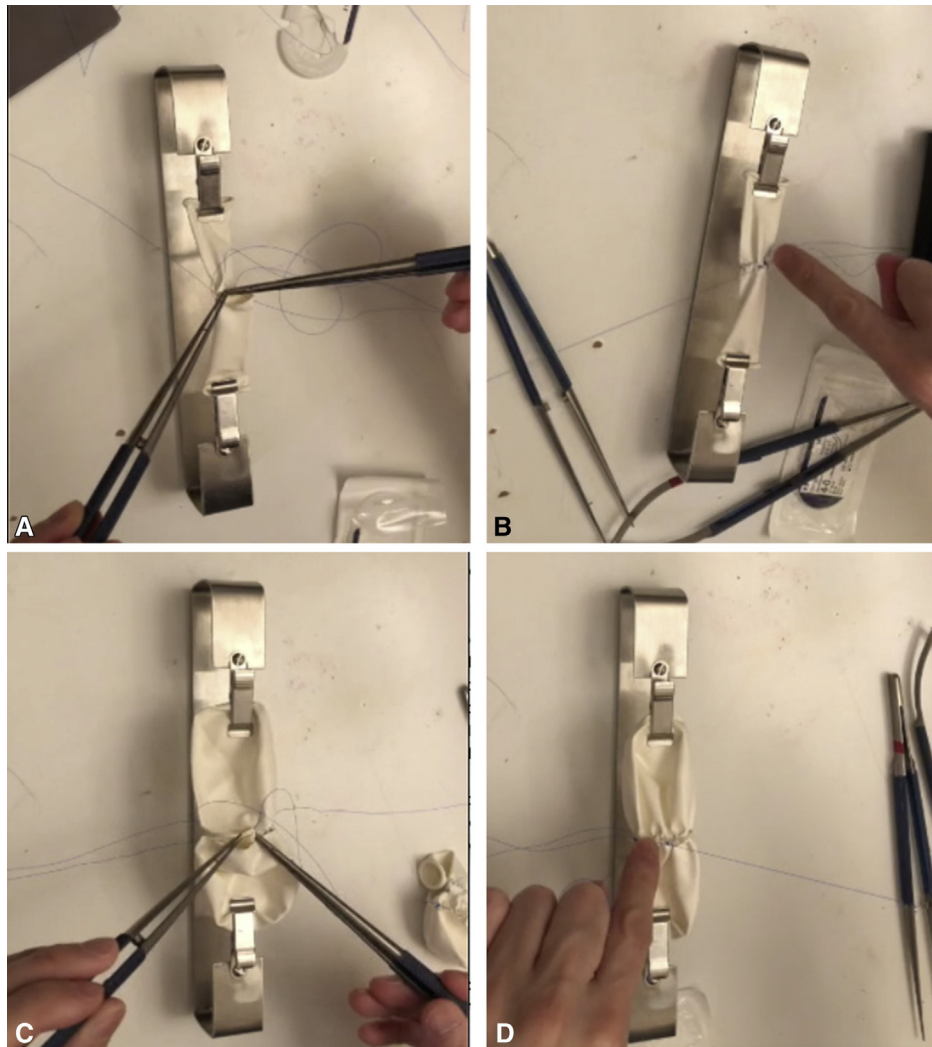
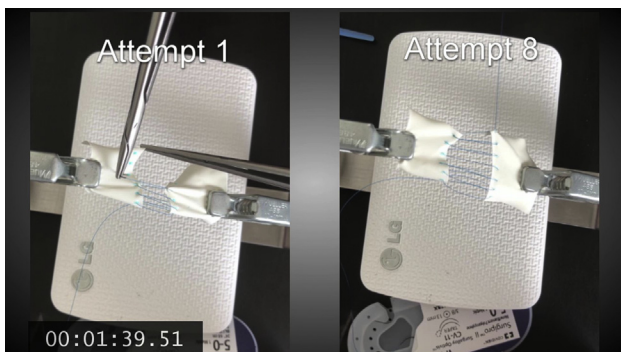


FIGURE 2. The bench model allows for demonstration of various surgical exercises simulating lung transplantation scenarios. A, Pulmonary artery anastomosis. B, Finished pulmonary artery anastomosis. C, Left atrial anastomosis. D, Finished left atrial anastomosis.

learning. The virtual sessions were held regularly over a 3-month period starting in mid-March 2020 and continuing until the partial resumption of lung transplantation activity in mid-May.



VIDEO 1. Improvement in surgical efficiency in a simulated model of vascular anastomosis after deliberate practice in a single training session. Video available at: [https://www.jtcvs.org/article/S2666-2736\(21\)00196-0/fulltext](https://www.jtcvs.org/article/S2666-2736(21)00196-0/fulltext).

Maintenance of Clinical Skills and Judgment

When possible during the pandemic, fellows played an integral role in patient care. Surgical fellows participated in the donor retrieval operations and assisted with implantation. Fellows were also primarily responsible for the day-to-day care of transplant recipients, as well as patients with COVID-19 who required extracorporeal membrane oxygenation support.

Didactic Sessions and Virtual Discussions

Another component of the curriculum was virtual education sessions, hosted by an attending surgeon and presented by the fellows. Topics (Table 1) were selected to be of direct relevance to surgical fellows and focused on both clinical judgment and management of difficult operative scenarios. Discussion was focused on the practical aspects of lung transplantation rather than on more academic or theoretical concepts.

Assessment

Throughout the course of the pandemic, informal feedback was sought from the participants to optimize learning in this novel format. At the end of the course, all fellows were interviewed and surveyed to obtain feedback on the virtual technical skills curriculum. Survey questions were developed in conjunction with the attending staff of the lung transplantation program.



FIGURE 3. Difficult surgical conditions in transplantation can be simulated using simple adjustments in the bench model. A, Standard pulmonary artery anastomosis with equal-sized cuffs. B, Pulmonary artery anastomosis with a short proximal cuff. C, Pulmonary artery anastomosis with steep angle of proximal cuff. D, Standard left atrial anastomosis. E, Left atrial anastomosis in deeper setting. F, Pulmonary artery and left atrial anastomosis with precise bite requirements.

TABLE 1. Selected surgical topics discussed at virtual education sessions

Management of bronchial complications
Redo lung transplantation
Management of a difficult left atrial anastomosis
Donor evaluation and management
Pediatric lung transplantation
Extracorporeal membrane oxygenation as a bridge to transplantation
Combined liver–lung transplantation
Combined heart–lung transplantation
Use of lung donors with a history of cigarette smoking

Participants were asked to evaluate their confidence in transplantation, realism of the model, and usefulness of the virtual skills sessions on a 5-point Likert scale. Individual responses were kept anonymous, and participation was voluntary.

The Toronto Lung Transplant Program database was interrogated to determine the warm ischemic time for the 5 transplantation procedures that each fellow was assigned (specifically, the ischemic time for the operative side performed by the fellow) both immediately before the restrictions on transplantation and on resumption of normal clinical activity. Between-group comparisons pre- and post-“lockdown” were performed using the independent-samples *t* test, with a *P* value ≤ .05 considered to indicate statistical significance.

RESULTS

During the 3-month period of the first wave of COVID-19 in Toronto, 12 lung transplantations were performed,

compared with 50 during the same period in 2019. Fellows also transitioned to managing patients with COVID-19 on extracorporeal membrane oxygenation, which, because of institutional policies at the time, required restrictions in contact with transplant recipients.

The virtual skills teaching course commenced in March, and a total of 12 skills teaching sessions were held, in addition to the ordinary academic program of the Lung Transplant Division, which includes didactic lectures, quality rounds, and journal clubs. All 7 senior surgical fellows included in the course were invited to participate in the survey and provide feedback. The year of graduation from medical school ranged from 2003 to 2012, and the fellows were an average of 13.9 years post-medical school graduation before entry into the lung transplant fellowship. All 7 fellows were male. In terms of training background, the average duration of general surgery training before the lung transplant fellowship was 2.7 years (range, 1-5 years); that of thoracic surgery training, 4.9 years (range, 2-10 years); and that of cardiac surgery, 2.0 years (range, 0-8 years). The average number of lung transplants performed as either the primary surgeon or an assistant before the COVID-19 pandemic was 25.9 cases.

Fellows reported spending an average of 5 hours (range, 1.3-15 hours) of home practice using the supplied equipment. Five out of 7 respondents (71%) reported self-described improvement in their technical skills after the technical skills curriculum. Five respondents (71%) reported increased confidence in performing a lung transplant when transplant activities resumed after 3 months, and 2 (28%) reported either no change or a slight reduction in confidence. [Figure 4](#) outlines the feedback received by fellows for the virtual technical skills curriculum.

Three fellows submitted individual videos for detailed analysis by staff surgeons, and all 3 respondents considered this a useful component of the curriculum. In 1 case, a participant halved the time taken to perform an exercise in surgical anastomosis after 8 repetitions and experimentation with different techniques ([Video 1](#)).

Specific feedback from the fellows was mostly positive. All understood the limitations and constraints during the pandemic period and appreciated any efforts to maintain or improve their technical skills. The most important positive feedback related to having a bench model to allow for independent practice, with the virtual meetings being perceived as slightly less essential. The most useful effect of regular meetings was motivation for fellows to continue practicing independently. Discussion of technical issues that occurred in recently performed clinical transplants was also helpful.

Representative feedback from one fellow received in the early phase of the virtual training sessions included *"I think evaluating one trainee at a time while all trainees were focusing on him and receiving feedback from the staff would*

have been interesting. It would have put more pressure on the trainee and the need to perform better. Also, a competition between trainees on the time to perform an anastomosis would have been interesting and pushed us toward faster improvement." Although the competitive aspect was not ultimately implemented, the group feedback and scrutiny aspect was an important modification during the development of this curriculum.

Fellows reported an increase in their confidence going into a lung transplantation after the extended break, and an increase in their self-assessed technical proficiency. Although not formally studied, most faculty surgeons (by consensus opinion of 8 thoracic surgeons who specialize in lung transplantation) did not see a large decay in the operative ability of the surgical fellows despite the 4-month interruption. The impact on case numbers affected the fellows' planned finish dates, with 1 of the 7 fellows extending their fellowship for 6 months.

Regarding the fidelity of the model, the trainees agreed that the bench model was not particularly realistic (average, 2.5 out of 5 points on the Likert scale). A representative comment from one trainee was *"the balloon material had different friction than the actual tissue and so had to pull through sutures more."* However, when asked whether realism was an important feature of the training model, trainees responded that it was still useful despite being low fidelity (3.1 out of 5 points).

Warm ischemic times were available for 6 fellows and are shown in [Figure 5](#) (1 fellow joined during the pandemic and did not perform any lung transplantations before the lockdown). One fellow had a statistically significant improvement in warm ischemic time (from 86.6 minutes to 63 minutes; $P = .05$). Overall, there was no statistically significant change in warm ischemic time in transplantations performed by the fellows before and after the lockdown (70.3 minutes vs 68.3 minutes; $P = .68$).

DISCUSSION

Before the COVID-19 pandemic, all standard clinical lung transplants were performed with 1 staff surgeon and 2 surgical fellows as assistants. In addition to donor lung preservation and retrieval, fellows had the opportunity to participate in all aspects of the surgery in the recipient, from opening and closing to performing the pneumonectomy and implantation. During the first wave of the pandemic, restrictions on the number of people allowed in the OR, the ability to attend transplant cases after managing COVID-19-positive patients, a strong desire to minimize operating time, and concerns about the adequacy and availability of personal protective equipment supply led to most cases being performed by staff surgeons rather than fellows under supervision. Because most fellows spend 1 year in the Toronto lung transplant surgical fellowship, the reduction in activity corresponded to one-quarter of a fellow's total time

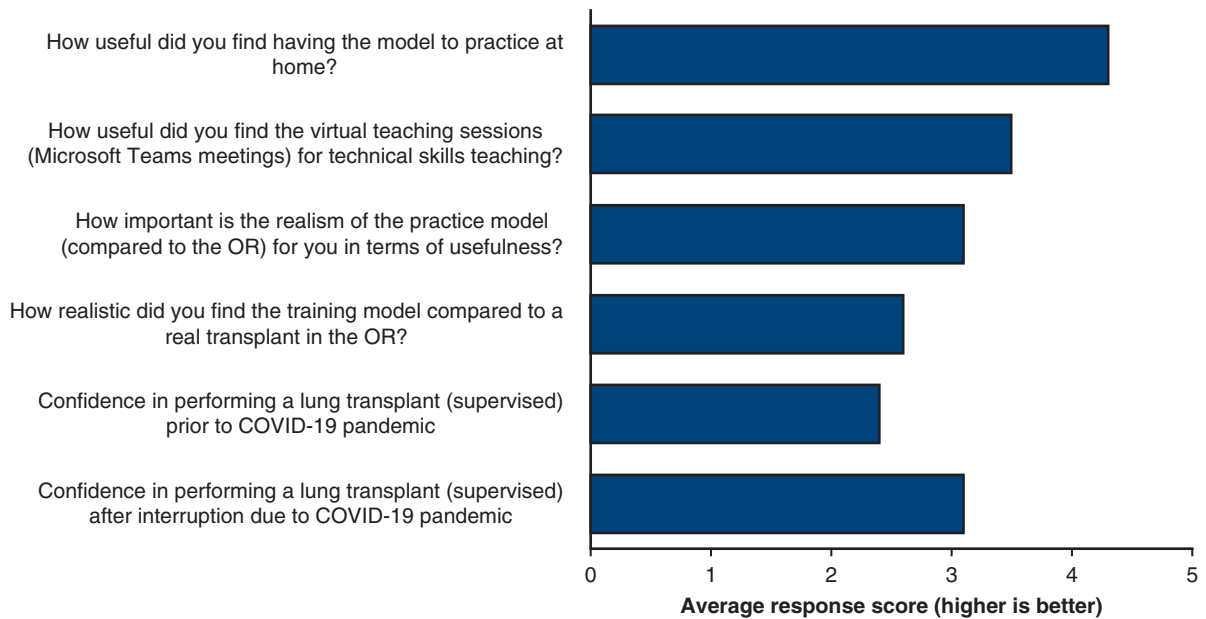


FIGURE 4. Feedback from surgical fellows about virtual technical skills teaching, including questions on confidence in performing the surgery pre-pandemic and postpandemic and the importance of realism in technical skills teaching. *OR*, Operating room; *COVID-19*, novel coronavirus.

in the fellowship program, with a significant impact on individual case volume.

The impact of time off has significant effects on surgeon productivity and even patient mortality, as reported by Hockenberry and Helmchen² in a cohort of patients undergoing coronary artery bypass surgery. Skill depreciation and increased patient mortality could be observed in surgeons with time away from the operating room in as little as

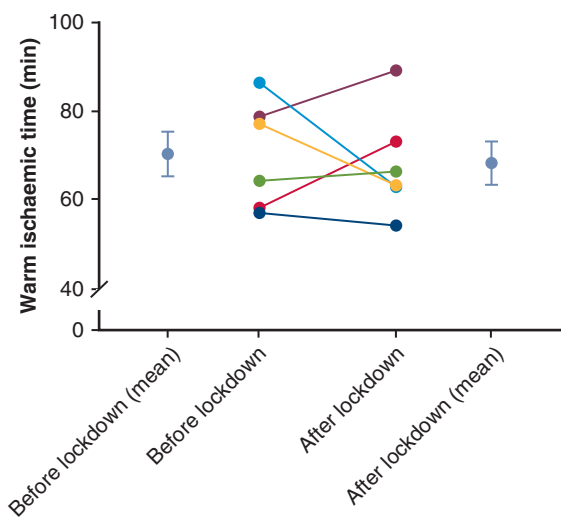


FIGURE 5. Average warm ischemic time of the last 5 lung transplantation procedures performed by the lung transplant fellows before the severe reduction of clinical activity due to the COVID-19 pandemic (lockdown) and following resumption of normal clinical activity. *Colors* indicate individual fellows.

2 weeks.¹ This impact could be reasonably expected to be even more pronounced with a prolonged interruption for senior-level trainees who are in the early phase of the learning curve for a new or complex operation. However, these concerns are somewhat attenuated by the unique characteristics of the fellows in an advanced transplant training program. Fellows ranged from postgraduate year 7 to 17, and most fellows had already completed previous senior surgical fellowships in cardiac or thoracic surgery or had been in independent practice before entering the lung transplant fellowship. Educational programs or simulations designed for undergraduate students or residents with the objective of teaching basic surgical skills (eg, suturing, knot tying, tissue handling) were not appropriate for trainees at this level of seniority. Most of the fellows had a considerable amount of lung transplantation experience before the start of the pandemic (average of 26 cases); thus, the basic steps of the procedure and flow of an operation did not have to be taught in simulation. Our curriculum focused on the development and maintenance of advanced surgical technical skills, dealing with surgical technique, efficiency, economy of motion, limited surgical access, and complex situations.

Video-based coaching has emerged as a promising technique to improve surgical performance, and online platforms are being developed to allow for group feedback on videos posted online.¹² Advantages include individual feedback that can be scheduled at a time convenient to the trainee and the coach, the ability to fast forward and replay segments of the procedure, and the ability for surgeons to review their own performance from a different perspective.

Minimally invasive and laparoscopic procedures are indeed natural targets for this technique of coaching, owing to the inherent use of video for the surgery, although it also has been applied to open procedures.¹³⁻¹⁶

It was clear that the fellows were generally competent when it came to the basic concepts of completing a vascular anastomosis; however, through analysis of the videos and live demonstration, we found that the necessary feedback was focused on fine-tuning issues related to dexterity, efficiency of motion, and operating in a space-restricted field. For example, as the course progressed, our sessions focused on discussing needle angles—a higher-level component of technical skills. It is evident that in designing technical skills courses for senior trainees, the learning objectives are very different and should be focused more on fine-tuning advanced skills rather than learning basic skills. A similar finding has been reported in the vascular surgery literature, with senior trainees and staff having less benefit than junior residents with purely basic proficiency-based practice.¹⁷

The finding of no overall deterioration in warm ischemic time (a rough surrogate for anastomotic time) indicated that the deliberate practice model showed promise in skill retention despite being away from the OR. Although limited by small numbers, and acknowledging that individual case factors can have a large effect on warm ischemic time, the fellow who improved most (from the longest ischemic time to the second shortest) participated fully in all aspects, including the video analysis and individual coaching. The improvement in surgical flow from this particular fellow is demonstrated in [Video 1](#) (shared with permission).

One important component of our course was the willingness of the participants to share their practice with the group and receive feedback from their peers and the staff surgeon. Although it is common for trainees to focus only on learning by doing, it is important to note that learning by observing is also an important component of learning a motor skill.¹⁸ Furthermore, it has been established that observing both flawed and flawless practice can improve skill learning, provided that trainees are aware of the components that are considered “errors.”¹⁹ Being encouraged to make errors during simulation has also been shown to improve skill transfer.^{20,21} The format of the course allowed the fellows to observe erroneous practice in their peers and to observe and learn from the feedback the peers received. It has been shown that this self-regulated learning method can result in successful learning through simulation as long as it is accompanied by educational support, which was provided by the biweekly educational sessions.^{22,23} In our experience, it was useful for trainees to learn through detailed analysis of one trainee’s performance per session, rather than to try to have each trainee go through the exercise in the limited time that each session allowed. Although our curriculum included no standardized method of

feedback, incorporation of a standardized scale for assessment²⁴ will be a useful component for future courses to improve objectivity.

Limitations

Limitations of this study include the small number of trainees included and the potential for internal bias, given the self-reporting of results. This limitation was a natural constraint owing to the COVID-19 pandemic, as the teaching sessions and bench model were developed expeditiously to minimize the disruption in training of the transplant fellows. Objective data regarding the fellows’ performance was difficult to obtain, and warm ischemic time is subject to many patient and environmental variables that are outside the control of the fellow performing the procedure.

Fidelity

Whereas very junior trainees may have found the balloon model of vascular anastomosis to be quite similar to real life, our very senior trainees were more sensitive to the subtlety of the feeling of using the balloon to suture. They felt that the suture had too much drag or friction as it went through the balloon, which is indeed quite a different feeling than a suture being pulled through a pulmonary artery. Thus, simulation courses for fellows must consider the more extensive surgical experience of the trainees and continue to strive to develop models that are as similar to real life as possible. As it may be challenging to make low-tech, nonanimal tissue models that are very high fidelity (ie, close to real life), we found that much benefit can be derived from changing the paradigm of the simulation. In this group learning activity, the goal was not to recreate the OR, but rather to create an environment in which specific skills can be practiced—specifically, ones that require observation and feedback that the time-pressured OR environment does not allow.

Technology Issues

An advantage of using this technique to teach technical skills lay in the ability to expeditiously apply easily available technology. The aim was to use equipment and technology that was universally available (mobile phone with recording capability) rather than specialized equipment that was difficult to deploy during the pandemic. Nonetheless, some trainees found it difficult to set up streaming video of their bench model while simultaneously observing the computer screen and listening to the audio component. The use of mobile phone cameras rather than laptop cameras allowed for increased portability, with trainees using a “selfie stick” or box to support the phone. Simultaneous use of a mobile phone to stream the bench model and a laptop (both simultaneously logged onto the same video conference) would allow for easier filming and coaching.

Maintaining technical proficiency in surgical fellows during the COVID-19 pandemic through virtual teaching

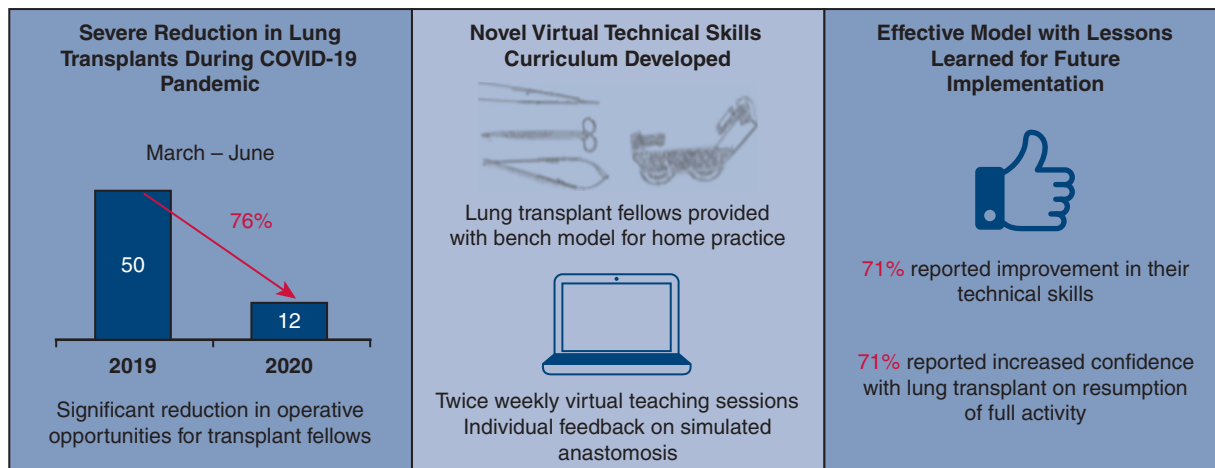


FIGURE 6. The significant reduction in lung transplants during the COVID-19 pandemic provided an opportunity to develop an innovative method of teaching technical skills. This program, specifically adapted for senior learners, includes virtual technical skills teaching with a novel bench model and live-time video coaching and sets the framework for the development of future virtual technical skills curricula. *COVID-19*, Novel coronavirus.

Newer low-cost cameras also have been used successfully to film simulation practice for future feedback.²⁵

Owing to the challenges of live streaming (which may be limited by home wi-fi bandwidth limitation), the use of individual video recording and feedback was pursued as an alternative. Difficulties also arose from having a single fixed viewpoint unable to show both the fine detail of the suturing (to demonstrate the accuracy of suture bites) and the overall operative field. Depending on the angle of recording, it was also occasionally difficult to gauge the 3-dimensional position of needles and sutures relative to the bench model.

Future Directions

The virtual technical skills teaching course was rapidly developed as necessary response to physical distancing measures because of the COVID-19 pandemic. As these restrictions were relaxed, face-to-face teaching and teaching in the operating room resumed, yet we feel that the lessons learned from our experience during this exceptional time can be used to create simulation curricula that will enhance the education of our more senior fellowship-level trainees.

The bench models that have been developed are low cost and in the future could be used for incoming fellows to allow them to develop proficiency at their own pace. Our department has consulted with biomedical engineers to develop more sophisticated tissue analogues, including one for bronchial and tracheal anastomosis. Improved surgical instrument kits (including a weighted shod clamp for suture management and various surgical clamps) also have been procured to improve the fidelity of the model. Ideally, as social distancing restrictions are relaxed, learners can begin to work in small groups with a portable model that

can be stored in the fellows' offices or call rooms, allowing for opportunistic learning during free time.

As lung transplants ramped up to approximately 10 to 15 per month, the model was not used as frequently. Our program intends to continue to use this model to on-board new fellows and to augment learning outside of the OR. We also intend to continue video recording of fellows performing transplant surgery both on the bench model and in the OR (using a headlight-mounted surgical camera) to expand this program of individual coaching and feedback. For complex procedures such as lung transplantation, which may be performed at varying frequencies depending on the program size, one could conceive of a program that guarantees that the trainee performs at least 1 lung transplant per week, whether simulated at home or live in the operating room.

CONCLUSIONS

The COVID-19 pandemic has had a significant effect on the surgical training of lung transplant fellows. Significant challenges presented owing to the need for physical distancing and the activity limitations of the transplant program in preparation for a potential surge of COVID-19 patients. Importantly, we recognize that the educational requirements for senior trainees differ from those of undergraduate students and residents. Maintenance of operative ability and prevention of skill depreciation was a priority for fellows during this period. A program of virtual technical skills teaching, individual video coaching, and provision of a bench model for independent practice was useful to maintain the skills and confidence of lung transplant surgical fellows (Figure 6).

Conflict of Interest Statement

The authors reported no conflicts of interest.

The *Journal* policy requires editors and reviewers to disclose conflicts of interest and to decline handling or reviewing manuscripts for which they may have a conflict of interest. The editors and reviewers of this article have no conflicts of interest.

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