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Lessons learned during the COVID-19 pandemic using virtual basic laparoscopic training in Santa Cruz de la Sierra, Bolivia: effects on confidence, knowledge, and skill

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Abstract

Background An international surgical team implemented a virtual basic laparoscopic surgery course for Bolivian general and pediatric surgeons and residents during the COVID-19 pandemic. This simulation course aimed to enhance training in a lower-resource environment despite the challenges of decreased operative volume and lack of in-person instruction.

Methods The course was developed by surgeons from Bolivian and U.S.-based institutions and offered twice between July-December 2020. Didactic content and skill techniques were taught via weekly live videoconferences. Additional mentorship was provided through small group sessions. Participants were evaluated by pre- and post-course tests of didactic content as well as by video task review.

Results Of the 24 enrolled participants, 13 were practicing surgeons and 10 were surgery residents (one unspecified). Fifty percent ($n=12$) indicated "almost never" performing laparoscopic surgeries pre-course. Confidence significantly increased for five laparoscopic tasks. Test scores also increased significantly (68.2% ± 12.5%, $n=21$; vs 76.6% ± 12.6%, $n=19$; $p=0.040$). While challenges impeded objective evaluation for the first course iteration, adjustments permitted video scoring in the second iteration. This group demonstrated significant improvements in precision cutting (11.6% ± 16.7%, $n=9$; vs 62.5% ± 18.6%, $n=6$; $p<0.001$), intracorporeal knot tying (36.4% ± 38.1%, $n=9$; vs 79.2% ± 17.2%, $n=7$; $p=0.012$), and combined skill (40.3% ± 17.7%; $n=8$ vs 77.2% ± 13.6%, $n=4$; $p=0.042$). Collectively, combined skill scores improved by 66.3% ± 10.4%.

Conclusion Virtual international collaboration can improve confidence, knowledge, and basic laparoscopic skills, even in resource-limited settings during a global pandemic. Future efforts should focus on standardizing resources for participants and enhancing access to live feedback resources between classes.

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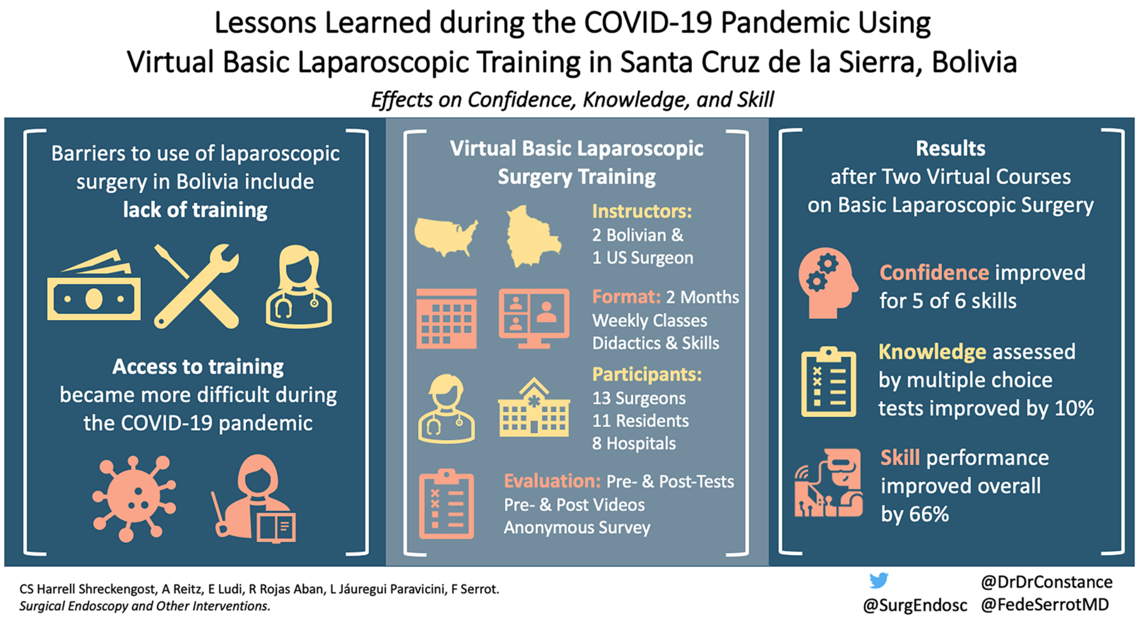
Graphical abstract



Keywords GLOBAL surgery · International collaboration · Laparoscopy · Simulation · Training · Virtual education

Laparoscopic surgery has become the standard of care in high-income countries (HIC) for many surgical procedures, including appendectomy and cholecystectomy. For such procedures in appropriately selected patients, laparoscopy confers significant advantages including decreased pain, lower complication rates, and decreased hospital length of stay [1–3]. Nonetheless, laparoscopy is still an emerging surgical technology in many low- and middle-income countries (LMICs), including Bolivia. Despite efforts to establish laparoscopic surgery programs in Bolivia dating back to the 1990s [4], laparoscopy has been partially adopted such that some tertiary care hospitals in major Bolivian cities only occasionally use these techniques.

The advantages of laparoscopic surgery are particularly important in low-resource settings, including reduced hospital length of stay, leading to faster turnover and reduced costs on already over-burdened systems; reduced medication use; and smaller wounds resulting in fewer surgical site infections [5]. Unfortunately, the barriers to laparoscopic implementation remain numerous, including high start-up costs for equipment, limited physical resources, and limited human resources [5]. The lack of human capacity is largely due to limited minimally invasive training opportunities. Surgeons and trainees rely on infrequent workshops or observation in the operating room, as designated laparoscopic fellowships are lacking [6, 7].

A team of Bolivian and United States-based surgeons sought to address this training gap by offering basic laparoscopic surgical training to pediatric and general surgeons in Santa Cruz de la Sierra, Bolivia in the summer and fall of 2019. Initial courses were met with much enthusiasm and demonstrated improvements in confidence and skill for basic laparoscopic skills [8]. These efforts met with successes similar to those described by others globally who have implemented laparoscopic training programs in countries including Argentina [9], Chile [10], Mongolia [11], Kenya [12], and Tanzania [13].

Due to the COVID-19 pandemic, however, original plans for continuing live in-person workshops in the spring of 2020 were postponed. Surgical education generally was profoundly impacted during the COVID-19 pandemic by reduced surgical volumes and increased safety concerns [14]. However, these limitations also encouraged greater use of innovative alternatives to live training with virtual conferences, simulation, and reliance on smartphone technologies [15, 16].

The Bolivian and U.S.-based surgical team took advantage of these virtual alternatives and pivoted to offer a virtual basic laparoscopic surgery course for surgeons and trainees in Santa Cruz de la Sierra, Bolivia between July 2020 through December 2020. The course combined didactic lectures on the essentials of laparoscopy, pneumoperitoneum, and electrosurgery with basic laparoscopic box trainer skill simulation, all offered via videoconferencing technology. Laparoscopic surgical box trainer simulation has been previously demonstrated to improve skills among those with little to no prior laparoscopic experience [17, 18], and thus this population was targeted for course participation.

Both the successes and challenges of the Bolivian virtual basic laparoscopy course and box trainer simulation are discussed and examined here. The course's effects on participant confidence, knowledge, and skill are assessed and presented as proof-of-concept educational cases from which subsequent training programs and international collaborations can be built.

Materials and methods

Course format

The basic virtual laparoscopy course for general and pediatric surgeons during the COVID-19 pandemic was designed by three attending surgeons, including one minimally invasive adult general surgeon from Emory University in Atlanta, GA, USA; a pediatric surgeon from the Hospital de Niños Mario Ortiz Suarez in Santa Cruz de la Sierra, Bolivia; and another pediatric surgeon from the Caja de Salud de la Banca Privada in Santa Cruz de la Sierra, Bolivia. All attending-level surgeons regularly used laparoscopy in their surgical practice. Three general surgery residents (clinical post-graduate years two to three) from Emory University also served as teaching assistants and co-course developers. All residents had successfully completed the Fundamentals of Laparoscopic Surgery course jointly offered by the Society of American Gastrointestinal and Endoscopic Surgeons (SAGES) and the American College of Surgeons (ACS) as part of their residency training prior to acting as teaching assistants for the virtual laparoscopy course. All three instructors were native Spanish speakers, while the three residents were native English speakers but with intermediate to advanced Spanish language skills. To ensure safety for all given that the course took place during the COVID-19 pandemic, all sessions occurred virtually. Instructors and participants observed masking and social distancing regulations and hand hygiene, particularly before and after using any shared materials, was encouraged.

The course was offered twice between July through December 2020. The first iteration of the course took place between July through September 2020, with nine 2-h virtual sessions offered once per week. The second iteration took place between November through December 2020, with seven 2-h virtual sessions offered once per week using the videoconferencing tool Zoom. The general format of the weekly sessions consisted of didactic lectures for the first hour of class, followed by discussion and demonstration of skills during the second hour of the class. During each iteration of the course, participants were divided into three small groups, with one attending surgeon, one teaching assistant resident, and between three to five participants in each group. Small groups met virtually outside the scheduled sessions for more personalized feedback and discussion at the discretion of the attending instructor.

Both iterations of the course offered the same didactic sessions: introduction to laparoscopy; pre- and post-operative evaluation of the pediatric patient for laparoscopy; physiologic effects of pneumoperitoneum; laparoscopic equipment; electrosurgery; and laparoscopic access. Lectures on these topics were provided in mixed format, with some lectures pre-recorded for participant viewing, and other lectures given live during weekly sessions. All live lectures were recorded and made available to participants after each session.

Both iterations of the course also taught the same four basic laparoscopic skills, namely, object transfer, precision cutting, intracorporeal knot tying, and extracorporeal knot tying. Pre-recorded videos describing techniques of all four skills were made available to participants from the start of each course. Directed live instruction in each technique was offered sequentially over subsequent sessions. At the start of each course, participants were asked whether they had access to box trainers and other materials needed to practice the activities. In case of no access to a trainer, a video describing how to create a box trainer using easily obtainable materials costing less than $15 US (Online Appendix One) was provided to all participants. This box trainer, originally developed in Mexico [19], requires only a smartphone or tablet in lieu of a computer as a video monitor, thus enhancing its accessibility.

To recruit participants, both Bolivian instructors shared a course advertisement and link to register for the course with colleagues at hospitals throughout the Santa Cruz region. Both pediatric surgeons and residents as well as general surgeons and residents who cared for pediatric patients as part of their standard practice were invited to participate. Attending-level surgeons were asked to pay 350 Bolivianos (~ $50 USD) while resident-level surgeons were asked to pay 150 Bolivianos (~ $22 USD) to participate in the course. These funds were used to obtain accreditation for the course from the Sociedad Boliviana de Cirugía (Bolivian Society of Surgery) and to create a fund to enable further training workshops.

All course documentation, videos, lectures, and communication were offered in Spanish. Communication between instructors and participants outside the live virtual sessions occurred using WhatsApp messaging (primarily) and email (secondarily). Course documents and videos were all maintained in Google Drive, with selected items made available to participants. During the first course, participants were instructed to upload their own videos to Google Drive; however, given multiple issues with video size and connectivity, participants were later asked to submit videos directly through WhatsApp. For the second course, all video submission occurred directly through WhatsApp.

Given the proof-of-concept nature of the course to provide accessible training throughout the COVID-19 pandemic in a specific setting (Santa Cruz de la Sierra, Bolivia), no ethics board approval was sought or obtained. While the tools Zoom, Google Drive, and WhatsApp were used throughout the course, specific endorsement from these companies was not sought or obtained; nor does the use of these tools during the course represent endorsement of these companies on the part of any instructor, resident, or participant.

Evaluation

Three methods of evaluation were used throughout the course. As part of the course registration form, participants provided basic demographic information, rated their confidence in laparoscopic ability, and described the frequency of their laparoscopic practice. At the end of the course, an anonymous post-course survey was distributed to all participants, soliciting the same rating in their confidence in laparoscopic abilities. This survey also inquired as to participant intent to use laparoscopy in the future and requested feedback on course benefits, challenges, and suggestions for improvement.

Both pre- and post-course, participants were asked to rate their confidence in their ability on several laparoscopic tasks as "0 (zero confidence)", "1 (very little confidence)", "2 (little confidence)", "3 (moderate confidence)", "4 (much confidence)", and "5 (confidence without doubt)". For the purposes of analysis, these categories were collapsed into "minimal" (ratings 0, 1, or 2); "moderate to high" (ratings 3, 4, or 5). Comparative analysis was performed between pre- and post-course confidence for the combined group as well as independent groups. Comparative analysis was also performed between groups at baseline and post-course. Due to the anonymous nature of the post-course survey, paired analyses were not possible.

Didactic content understanding was evaluated by a 16-question multiple-choice online tests (Online Appendix Two) at the start and end of the course (post-test). Percentage score was calculated and compared for pre- and post-tests.

Skill ability was evaluated via video submission. In the first course iteration, participants were asked to submit videos to Google Drive of all four activities at the start of the course; halfway through the course; and at the end of the course. Rubrics grading each activity were provided to instructors and participants to guide evaluation and practice. Given significant issues impairing video submission and evaluation as described in the Results section, the format was altered for the second iteration of the course so that participants took video using their mobile telephones and submitted videos directly via WhatsApp. Videos were also limited to a five-minute maximum duration. Only initial (pre-course) and final (post-course) videos were requested. Rubrics were altered slightly to account for differences in access to materials; these finalized rubrics are displayed in Online Appendix Three.

Statistical analysis

All data collected throughout the course was maintained in Google Sheets and then converted to comma-separated values (.csv) files for analysis using R Studio Version 1.4.1717. Descriptive analysis was performed for both iterations of the course independently, named "Group One" and "Group Two". Additional descriptive analysis was performed for data collected from both groups together and labeled "Combined". Comparative analyses were performed comparing pre- and post-course test scores, confidence levels, and skill abilities using Student's t tests, Wilcoxon rank sum tests, and Fisher's exact tests as appropriate. Paired analyses were performed when possible. Comparative analyses using these same test types were also performed between Group One and Group Two to assess for differences both at baseline and at the conclusion of the course. Significance was set to alpha of 0.05.

Results

Participant demographics

A total of 24 surgeons participated in the course, with 13 surgeons in Group One, representing three different hospitals, and 11 surgeons in Group Two, representing six different hospitals (Table 1). The participant population was 63% male ($n = 15$), evenly split by age younger or older than 35 years, and approximately evenly split by level of training (42% residents, $n = 10$; 57% attendings; $n = 13$; one participant not specified). Fifty percent ($n = 12$) of participants reported almost never using laparoscopy in their practice; none reported using laparoscopy once a week or more. Groups only differed in years of practice among attending participants, with 86% ($n = 6$) of attendings in Group One having less than 5 years of experience in practice and 83% ($n = 5$) of attendings in Group Two having more than 5 years of experience in practice.

Pre- and post-course surveys

Confidence

All 24 participants completed pre-course surveys, and 14 participants completed post-course surveys. In this survey,

Table 1 Virtual basic laparoscopic skills course: participant demographics

	Group one	Group two	Combined	*P*
Sample size *N*	13	11	24	
Different hospitals represented *N*	3	6	8	
Sex *N* (%)				
Female	6 (46)	3 (27)	9 (38)	0.423
Male	7 (54)	8 (73)	15 (63)	
Age *Missing* = 2; *N* (%)				
Under 35 years	8 (62)	3 (33)	11 (50)	0.387
35+ years	5 (38)	6 (67)	11 (50)	
Level of training *Missing* = 1; *N* (%)				
Resident	5 (42)	5 (45)	10 (42)	1
Attending	7 (58)	6 (54)	13 (57)	
Years in practice (attendings) *N* (%)				
Less than 5	6 (86)	1 (17)	7 (54)	0.029
5 or more	1 (14)	5 (83)	6 (46)	
Frequency of laparoscopy *Missing* = 1; *N* (%)				
Almost never	8 (62)	4 (36)	12 (50)	0.217
2–3 times per month	4 (31)	7 (64)	11 (46)	
Once a week or more	0 (0)	0 (0)	0 (0)	
Access to a box trainer *N* (%)				
No	2 (15)	1 (9)	3 (13)	1
Yes	11 (85)	10 (91)	21 (88)	

Data represented as number (*N*) or number and percent of total (*N*, %). Percentages may not sum to 100 due to rounding. *P* values calculated by Fisher's exact tests comparing Group One to Group Two; significance set at alpha of 0.05

participants reported significant improvements in confidence pre-course to post-course in several areas (Table 2). The frequency of reporting moderate or high levels of confidence in laparoscopic access improved from 58% ($n = 14$ of 24 total responses) to 93% ($n = 13$ of 14 total responses) ($p = 0.042$). Frequency of reporting moderate or high levels of confidence in object transfer (pre-course: 54%, $n = 13/24$; post-course: 100%, $n = 14/14$; $p = 0.003$), precision cutting (pre-course: 46%, $n = 11/24$; post-course: 93%, $n = 12/13$; $p = 0.011$), intracorporeal knot tying (pre-course: 25%, $n = 6/24$; post-course: 71%, $n = 10/13$; $p = 0.008$), and extracorporeal knot tying (pre-course: 33%, $n = 8/24$; post-course: 71%, $n = 10/13$; $p = 0.042$) similarly improved. Only confidence in instrument handling did not significantly improve (pre-course: 58%, $n = 14/24$; post-course: 86%, $n = 12/13$; $p = 0.147$).

At baseline, Group Two reported significantly greater frequency of moderate to high confidence in laparoscopic access (Group One: 38%, $n = 5/13$; Group Two: 82%, $n = 9/11$; $p = 0.047$), instrument handling (Group One: 38%, $n = 5/13$; Group Two: 82%, $n = 9/11$; $p = 0.047$), and object transfer (Group One: 23%, $n = 3/13$; Group Two: 91%, $n = 10/11$; $p = 0.001$) than Group One. Post-course, however, there was no significant difference in confidence levels reported for any activity between groups. When Group One and Group Two were assessed independently for changes pre-course to post-course, a greater frequency of moderate to high confidence was reported for all activities post-course in both groups, but the statistical significance of these improvements in confidence was no longer observed. In terms of hours spent towards improving their skills, 64% ($n = 9$) of participants reported practicing laparoscopic skills less than 3 h total throughout the course.

Feedback

In the anonymous post-course survey, participants rated the course as "poor", "fair", "satisfactory", "good", or "excellent". Seventy-one percent ($n = 10$ of 14) of participants rated the course as "good" while 29% ($n = 4$ of 14) rated the course as "excellent". Group One and Group Two participants did not differ in course ratings. No participants rated

Table 2 Level of confidence in laparoscopic tasks pre- and post-virtual course

Confidence level[a]	Group one			Group two			Combined		
	Pre	Post	P[b]	Pre	Post	P[c]	Pre	Post	*P*[d]
Sample size *N*	13	8		11	6		24	14	
Access *N* (%)									
Minimal	8 (62)	1 (13)	0.042	2 (18)	0 (0)	0.515	10 (42)	1 (7)	0.030
Mod–high	5 (38)	7 (88)		9 (82)	6 (100)		14 (58)	13 (93)	
Instrument handling *N* (%)									
Minimal	8 (62)	2 (25)	0.183	2 (18)	0 (0)	0.515	10 (42)	2 (14)	0.147
Mod–high	5 (38)	6 (75)		9 (82)	6 (100)		14 (58)	12 (86)	
Object transfer *N* (%)									
Minimal	10 (77)	0 (0)	0.001	1 (9)	0 (0)	1	11 (46)	0 (0)	0.003
Mod–high	3 (23)	8 (100)		10 (91)	6 (100)		13 (54)	14 (100)	
Precision cut *N* (%) *Missing* = 1									
Minimal	8 (62)	1 (14)	0.070	5 (45)	0 (0)	0.102	13 (54)	1 (8)	0.011
Mod–high	5 (38)	6 (86)		6 (54)	6 (100)		11 (46)	12 (92)	
Intra-corporeal *N* (%)									
Minimal	11 (85)	3 (38)	0.056	7 (64)	1 (17)	0.131	18 (75)	4 (29)	0.008
Mod–high	2 (15)	5 (63)		4 (36)	5 (83)		6 (25)	10 (71)	
Extra-corporeal *N* (%)									
Minimal	10 (77)	3 (38)	0.164	6 (54)	1 (17)	0.304	16 (67)	4 (29)	0.042
Mod–high	3 (23)	5 (63)		5 (45)	5 (83)		8 (33)	10 (71)	

[a]Participants reported level of confidence in specific skills out of a six-factor scale; the three lowest levels were combined as "minimal" confidence and the three highest levels were combined as "mod–high" (moderate to high) confidence for the purposes of analysis

[b]*P* value calculated by Fisher's exact tests comparing pre-course to post-course survey responses among Group One participants

[c]*P* value calculated by Fisher's exact tests comparing pre-course to post-course survey responses among Group Two participants

[d]*P* value calculated by Fisher's exact tests comparing pre-course to post-course survey responses among all participants irrespective of group. Data represented as number (*N*) or number and percent of total (*N*, %). Percentages may not sum to 100 due to rounding. Significance set at alpha of 0.05

the course as satisfactory or worse. One hundred percent ($n = 14$ of 14) of post-course survey respondents agreed that the course was useful and that the instructors were helpful. All participants similarly stated that they would recommend the course to colleagues and that they anticipated using laparoscopy more in the future.

While no formal qualitative analysis was performed, additional insight was obtained from the free-text responses to questions regarding the best and worst aspects of the course as well as requests for suggestions to improve. The best aspects of the course reported included interaction with instructors, feedback with tricks and tips for the activities, and improved confidence. The worst aspects of the course reported included inadequate resources for practice, lack of time for practice, and difficulty obtaining and sending videos. Suggestions for improvement largely centered on increasing the amount of time for live feedback on skill performance with instructors and improving the video submission process.

Pre- and post-course tests of didactic content

The combined group pre-course scores on tests of didactic content averaged 68.2% ± 12.5% ($n = 21$) while post-course scores averaged 76.6% ± 12.6% ($n = 19$), representing 10% improvement from baseline (Fig. 1). Eight participants lacked a pre-test, a post-test, or both; given that this comprised one third of the total participant population, unpaired analysis was performed. This unpaired analysis showed significant improvement between pre- and post-course scores ($p = 0.040$). However, when paired analysis was performed as possible, improvement did not reach significance ($p = 0.064$, $n = 16$).

A significant difference in baseline knowledge between groups was also detected, with Group Two scoring approximately 10 percentage points higher on the pre-test than Group One (Group Two: 73.3% ± 10.5%, $n = 11$; Group One: 62.5% ± 12.5%, $n = 10$; $p = 0.047$). Post-test scores did not differ between groups ($p = 0.725$, $n = 19$). Group

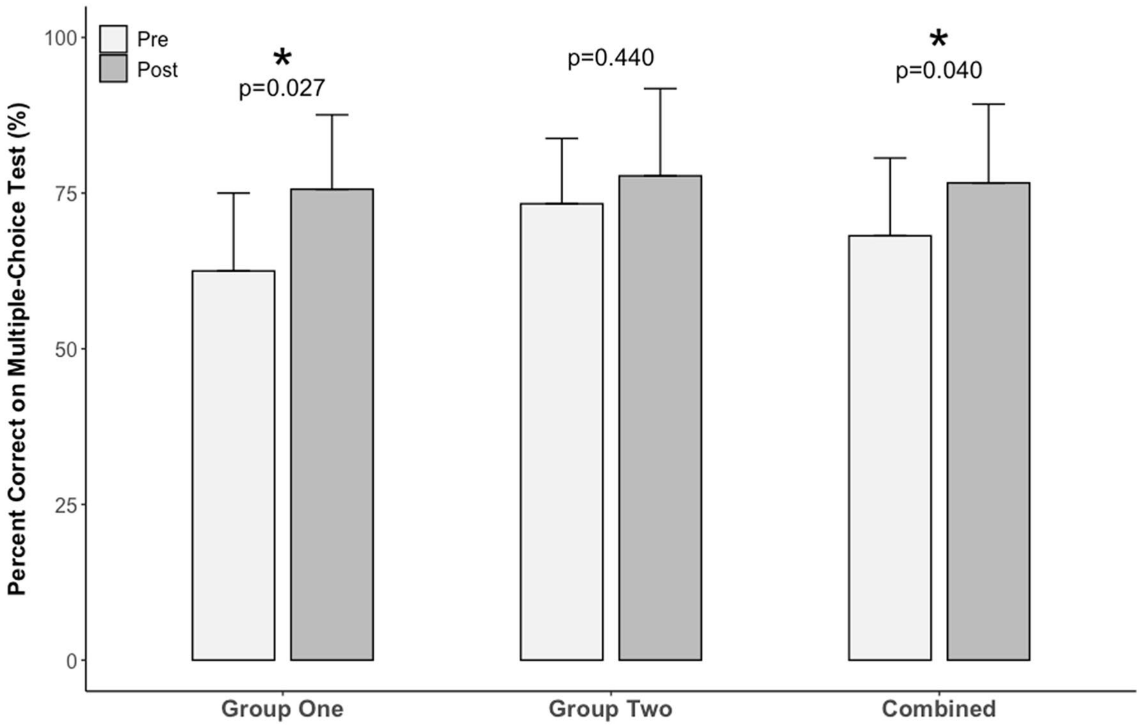


Fig. 1 Pre-course and post-course scores on multiple-choice tests of laparoscopic theory. Scores were calculated as the percent correct on a 16-question multiple-choice test of laparoscopic theory taken both prior to the course ("pre"; light gray) and after the course ("post"; dark gray). *P* values, shown above bars, were calculated by unpaired Student's t-tests and Wilcox rank sum, selected based on data normality. Calculations were performed among participants in Group One; among participants in Group Two; and among all participants combined. *Statistical significance (alpha = 0.05)

One improved 18.7% ± 19.3% from baseline, a difference significant both in unpaired ($p = 0.027$, $n = 16$) and paired ($p = 0.045$, $n = 7$) analysis. However, Group Two showed no significant improvement with only 3.2% ± 17.6% change from baseline scores (unpaired $p = 0.440$, $n = 11$; paired $p = 0.608$, $n = 9$).

Pre- and post-course skill videos

Group One experienced significant challenges with video acquisition and submission, impairing the ability to evaluate their skills. While 85% ($n = 11$) participants in Group One successfully submitted initial videos with attempts at object transfer and precision cutting, none successfully submitted initial knot-tying videos. In addition, several of these "initial" videos were submitted as late as the sixth week of the course. Only 38% ($n = 5$) successfully submitted a complete collection of videos of all four activities for final evaluation. Only 46% ($n = 6$) submitted final videos for object transfer and precision cutting, while 62% ($n = 8$) submitted final videos for both intracorporeal and extracorporeal knot tying. Even among the successfully submitted videos, multiple factors impaired evaluation. This included poor video quality, with inability to fully view tasks and lack of standardized materials despite the material list provided to participants and description of materials needed in pre-recorded activity videos. For example, participants used materials ranging from woven gauze to various fabric types for precision cutting. For object transfer, several participants used handmade pegboards with nails, corkboard, and sponges. Instruments also varied, with participants using laparoscopic Debakey, Allis, or Alligator-type graspers instead of Maryland dissectors. Suture material similarly differed, and several students used materials other than Penrose drains for knot tying. Thus, while written instructor feedback was provided to all students based on their videos, no formal objective scoring was possible for Group One.

To obviate many of the issues with video acquisition and submission encountered in Group One, participants in Group Two were provided the list of recommended materials prior to the course start. The importance of material selection was impressed upon participants at the start of the course. Specific recommendations were made to accommodate those participants who lacked access to standardized equipment. Participants were permitted to submit videos directly via WhatsApp with multiple attempts possible and in multiple segments if videos were too large to send as a single file. The grading rubric was also adjusted. Nonetheless, only 73%

($n=8$) participants successfully submitted all four initial skill videos, while only 36% ($n=4$) submitted all four final skill videos, with complete pre- and post-course video sets available for only 27% ($n=3$) participants.

Despite the barriers, formal objective skill evaluation was possible on a skill-by-skill basis for Group Two participants (Fig. 2a–e). Points were calculated based on the grading rubric and a percentage score of 100 was calculated. An additional combined skill score was calculated by summing points obtained in each independent activity and calculating the percentage of total obtained for those participants who submitted complete sets of all videos. Due to the large number of missing videos, comparative analyses were performed both in an unpaired and paired fashion.

The combined skill score improved from 40.3% ± 17.7% ($n=8$) pre-course to 77.2% ± 13.6% ($n=4$) post-course (unpaired: $p=0.042$; paired: $p=0.005$, $n=3$; Fig. 2e). This represents a 66.3% ± 10.4% increase from the baseline combined skill score. All individual participant scores in all activities increased between pre-course and post-course

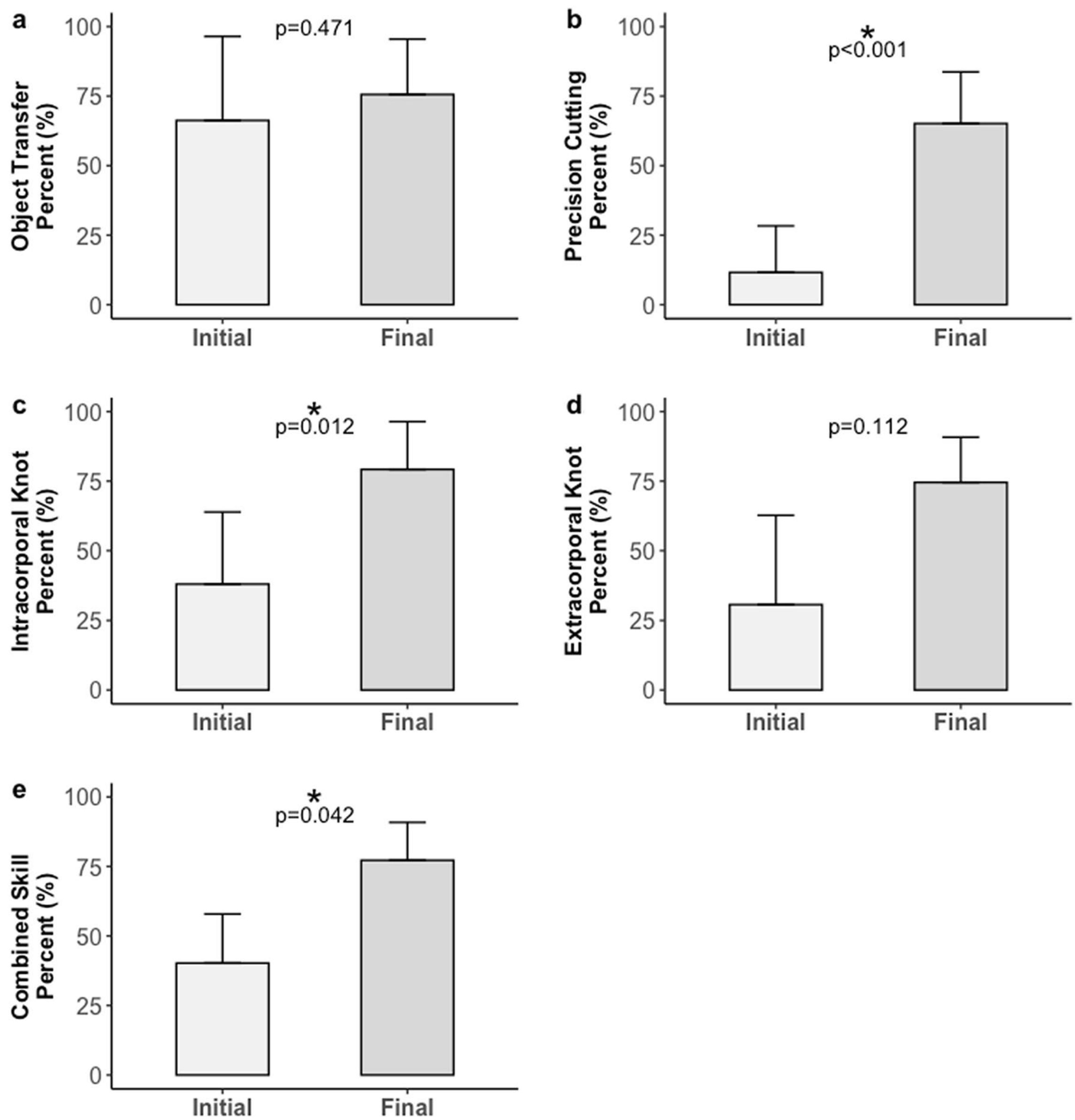


Fig. 2 Pre-course and post-course evaluation of basic laparoscopic skills. Scores were calculated as the percent of points obtained out of the total points available using rubrics for each individual task, including Object Transfer (**a**), Precision Cutting (**b**), Intracorporeal Knot Tying (**c**), and Extracorporeal Knot Tying (**d**). A combined score (**e**) was determined by the percent of points obtained out of the total points available for all tasks. Initial (light gray) and final (dark gray) videos were compared and *P* values, shown above bars, were calculated by unpaired Student's *t* tests and Wilcox rank sum tests, selected based on data normality. *Statistical significance (alpha = 0.05)

videos. However, this improvement was only independently significant for precision cutting (pre-course: 11.6% ± 16.7%, $n = 9$; post-course 62.5% ± 18.6%, $n = 6$; unpaired: $p < 0.001$; paired: $p = 0.004$, $n = 6$; Fig. 2b) and intracorporeal knot tying (pre-course: 36.4% ± 38.1%, $n = 9$; post-course 79.2% ± 17.2% $n = 7$, unpaired: $p = 0.012$; paired: $p = 0.031$, $n = 6$; Fig. 2c).

Discussion

The many advantages of laparoscopy make it the standard-of-care technique for many surgical procedures in HIC, yet use of laparoscopy in LMICs such as Bolivia remains limited due to barriers including lack of training opportunities [6, 7]. Despite the added challenges imposed by the COVID-19 pandemic, a team of Bolivian and U.S.-based surgeons sought to address this issue by creating a virtual basic laparoscopic surgery course teaching both didactic content and box trainer skills to Bolivian surgeons with minimal prior laparoscopic experience. While specific outcomes varied by course iteration, participants collectively reported higher levels of confidence in laparoscopic abilities, improved by 10% on tests of didactic content, and demonstrated a 66% improvement from baseline technical skills.

The course described here draws on techniques used by other programs, but it adapts these techniques to the local Bolivian context for appropriate dissemination during a global pandemic. Laparoscopic simulation using box trainers is now a well-recognized technique for teaching basic laparoscopic skills to learners with little laparoscopic training [17, 18]. The "Fundamentals of Laparoscopic Surgery" (FLS) program offered by the ACS and SAGES since 2005 is an educational program with web-based 14 modules and a box trainer skills component that has been shown to improve operating room performance in U.S. general surgery residents [20]. Purchase of a voucher costing $525 USD is required to take the FLS examinations. Successful completion of FLS has been a requirement for U.S. general surgery certification since 2008 [21].

Other laparoscopic programs also exist outside the U.S. The Go Global Program from SAGES has developed "GLAP", a training program focused on teaching the skills necessary for safe laparoscopic gallbladder surgery. This program has been implemented in both Mexico [22] and Costa Rica [23], where participants have shown increased confidence in their ability to perform laparoscopic cholecystectomies safely. In Chile, a basic skills program is combined with virtual reality modules with ex vivo tissue model simulation to create a more advanced laparoscopic skill program that has resulted in greater exposure to laparoscopic surgery during training [10]. Tele-mentoring via a mobile application called "Lapp" has also successfully improved laparoscopic hand-sewn jejunojejunostomy performance among Chilean surgical trainees [16]. In Argentina, low-cost simulation trainers and tele-mentoring were also used to continue offering basic laparoscopic skills training during the COVID-19 pandemic [15].

The course described here stands out in several ways. Offered virtually via videoconferencing, the course had live lectures and opportunity for direct interaction with attending surgeon instructors and resident teaching assistants. Regular small group interaction and personalized feedback via text, voice, or video was also provided. Given the interest of Bolivian surgeons and residents in applying laparoscopy to their pediatric surgical population, specific themes pertaining to laparoscopy in pediatric populations were added. Moreover, the skills and skill evaluation methods were adapted to the population in question. Participants were provided instruction to create their own box trainers at home. Exceptions were made to allow for use of non-standardized materials in object transfer, cutting, and knot tying. While these adaptations make direct comparison to other programs and between-participant evaluation more difficult, such flexibility is essential to working in a lower-resource environment.

The successes achieved by this course are multiple. First, significantly more participants reported moderate to high levels of confidence in five out of six laparoscopic abilities after taking the course than before. Second, participants demonstrated significant improvements on post-course tests of laparoscopic theory, with an average of a 10% increase from baseline test scores. Third, for the cases in which objective skill evaluation was possible, course participants demonstrated significant improvement with an increase of 66% from baseline on overall manual task performance. Specific improvements in precision cutting and intracorporeal knot tying were also observed.

Perhaps most essentially, the course provided an ongoing opportunity for surgeons and residents to interact, learn, and practice manual skills despite reduced surgical volumes and absence of other educational opportunities due to the COVID-19 pandemic. The diversity of the participant population, representing eight Bolivian hospitals with approximately equal distribution of residents and attending surgeons and heterogeneity of age and years in practice, shows that basic laparoscopic simulation courses remain important for a wide spectrum of surgeons in this country where laparoscopy has not yet become standard-of-care. Finally, the international relationships fostered among Bolivian and U.S. surgeons and residents have created a foundation permitting further bi-directional exchange.

The virtual basic laparoscopy course described was not without its challenges, however. Video submission represented the greatest challenge, as many participants found the process required for uploading to Google Drive confusing and cumbersome. Therefore, the video submission format shifted from Google Drive to WhatsApp for the second course iteration. This required a larger time commitment on the part of the resident teaching assistants to subsequently process and distribute videos with other instructors, but this shift in responsibility was reasonable given the U.S.-based residents' better access to reliable Internet and computers. In addition, inconsistent materials impaired the ability to evaluate participant performance. Instead of requiring purchase of high-cost standardized materials, however, the options were broadened to enable participants to select appropriate tools that were already available to them. For example, cardboard pegs were recommended over metal washers when rubber pegs were not available for object transfer, and simple cotton cloth recommended over woven gauze when non-woven gauze was not available for precision cutting.

Course evaluation was also hampered by participant failures to complete surveys and take tests. Given the voluntary nature of the course as well as the extensive additional demands on physicians and residents, particularly during the COVID-19 pandemic, many participants were unable to complete all course requirements. Test and activity score analysis originally planned as paired comparisons were performed in an unpaired fashion to maximize sample size. Within-group analysis was hindered by missing results and small sample size. Thus, while collective improvements were observed in confidence and test performance, such improvement cannot be conclusively declared when assessing outcomes within each group. At baseline the two groups were only notable for a significant difference in length of time in practice among attending physicians. While not statistically significant, however, a greater proportion of participants in Group Two relative to Group One reported moderate to high confidence for all laparoscopic skills examined prior to the course start. Participants in Group Two also had a numerically greater, though not statistically significantly greater, mean pre-test score compared to those in Group One. Unsurprisingly, only Group One independently showed significant improvements in confidence and test scores. Nonetheless, Group Two participants did independently demonstrate significant improvements in skill ability, indicating that the course was effective in this realm.

The basic virtual laparoscopic surgical course described here was developed as a proof-of-concept alternative to enable ongoing education during the COVID-19 pandemic pertaining to a valuable skill, namely, laparoscopic surgery. It was developed for specific surgical populations in Santa Cruz de la Sierra, Bolivia, and thus results are not generalizable to all locations in Bolivia, let alone all LMIC. Nonetheless, the course does provide a framework both for course development in other locations and for development of more advanced courses in Santa Cruz de la Sierra. Future studies will be needed to determine whether the confidence, knowledge, and skills obtained persist over time. Additional future directions include the development of additional virtual courses with personalized instruction to improve skills using both simulation in ex vivo models and videos of live surgeries. As the courses evolve, a "train the trainers" approach, in which participants learn to teach laparoscopic concepts and skills to others, will be adopted to ensure sustainability.

In conclusion, Bolivian-U.S. collaboration in the form of a virtual multi-week course on basic laparoscopic surgery successfully improved confidence, knowledge, and technical skills in a population of Bolivian surgeons and trainees with little laparoscopic training. This course was not only implemented in a low-resource setting generally, but also successfully delivered during the global COVID-19 pandemic. The successes of this course can guide development of additional courses in other low-resource settings and more advanced courses, taking advantage of the international collaboration already established and using a "train the trainers" model.

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Declarations

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