

ORIGINAL ARTICLE

The GlobalSurgBox: reducing medical student barriers to surgical simulation training

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Abstract

Background: Surgical simulation is central to the education of surgical trainees. Medical students desire early training but experience barriers such as high cost, lack of guidance, and inability to modify trainers with advancing skills. We hypothesize that the GlobalSurgBox platform will overcome many perceived barriers to the use of surgical simulation by medical students. **Methods:** Forty-five medical students from the University of Colorado School of Medicine were provided a GlobalSurgBox during in-person training events. Learners viewed instructional videos, then divided into small groups for surgical technique training, guided by volunteer surgical residents. Students were asked to complete a voluntary, anonymous survey regarding their experience. **Results:** Of the 45 participants, 30 completed the survey. There was a statistically significant increase in the pre-training comfort levels of using forceps ($P = 0.02$), two-handed knot tying ($P = 0.03$), and suturing ($P = 0.04$) after a single exposure to the GlobalSurgBox simulator. Eighty percent strongly agreed that the GlobalSurgBox encouraged practice, 53% felt more prepared for the operating room, and 67% deemed the trainer modifiable to meet advancing skills. **Conclusions:** When utilized by medical students in the setting of video and hands-on instructional training, medical students reported that practice on the GlobalSurgBox made them feel more prepared to enter the operating room and increased comfort with basic surgical techniques. The GlobalSurgBox is seen as an affordable, encouraging, and modifiable trainer, thereby reducing perceived barriers to surgical simulation use.

Keywords: surgical simulation; medical students; education; skills training; low-fidelity simulation

Introduction

Simulation training in surgery has become an increasingly central component of surgical education.^{1,2} The integration of low- and high-fidelity surgical simulators across all levels of training has shown successful transfer of skills to the operating room.^{3,4} For many medical students, the introduction of surgical simulation begins with the use of suture and knot-tying skills trainers. The use of such trainers promotes familiarity and practice with individual tasks before students perform them on patients in the clinical space.⁵ Prior studies suggest that as little as a single exposure to surgical simulation allows medical students to improve foundational surgical skills while also increasing students' confidence in their abilities to contribute to team-based practice in the operating room.^{6,7} Similarly, such exposures have the

potential to increase medical students' interest in pursuing a surgical career.^{7,8}

Early hands-on simulation has shown to have a positive impact on medical students' interest in pursuing surgery; however, its incorporation into medical school curricula is lacking.⁹ Many simulators available on the market are expensive, do not include access to training guides, and are not readily adaptable to meet trainee needs as their skills improve.^{10,11} Thus, there remains a need for an introductory surgical simulator that allows medical students to not only practice basic surgical skills, but also receive guidance and tools needed for the development of good habits during practice and self-assessment. Similarly, there is a need for surgical simulators that are modifiable, allowing for advancement of skills through the early stages of

learning, without having to purchase multiple costly simulators targeting each skill.

To overcome these barriers for medical students, our team utilized the GlobalSurgBox: a portable, durable, low-cost surgical simulation trainer that can be easily adapted to any level of training, ranging from medical students to surgical residents and fellows. The GlobalSurgBox was designed to help overcome common barriers to implementation including costs, time, and accessibility to training resources. Given the value of video-based instruction for early learners,¹² our team further developed www.GlobalSurgbox.com, a free platform for online learning modules and instructional aids that guides users through the use and modification of GlobalSurgBox to support training needs. Online modules include video of instruction in basic suture techniques and were developed under the expert guidance of Dr Yihan Lin, an author on this investigation and a board-certified cardiothoracic surgeon. We simplified access to the online training resources by including a QR code in the trainer which directed users to the website. We hypothesized that the GlobalSurgBox, with the addition of www.GlobalSurgBox.com learning resources, would overcome many barriers to use of surgical simulation models in medical students as well as aid medical students in their preparation for the use of introductory skills in the operating room (OR).

Materials and methods

The GlobalSurgBox (Fig. 1) is a low-fidelity surgical simulator developed for approximately US \$25 per kit. It

contains easily obtained and reusable supplies enclosed in a 12.5-inch toolbox for portability. The materials enclosed include a wooden template on which to perform different training modules and surgical tools and supplies that are modifiable to the trainee's skill level (Fig. 2). For instance, a shoelace is included for those learning to tie surgical knots, a yoga mat square for practicing subcuticular sutures, and a cardboard tube to simulate deep cavity knot tying as suture skills advance.

Forty-five medical students from the University of Colorado School of Medicine were each provided with one GlobalSurgBox surgical simulation trainer. At in-person training events, learners watched short instructional videos on surgical knot tying found on the GlobalSurgBox website at www.GlobalSurgBox.com. Students were then instructed on the simulator's use in small groups by volunteer surgical residents from the University of Colorado. Exercises included one- and two-handed knot-tying and basic suturing techniques. Following 1 h of simulation instruction using the trainer, students were asked to fill out a voluntary online questionnaire (Appendix 1) based on their experiences using the GlobalSurgBox. The questionnaire was developed by the authors of this study and was not based on any previously validated questionnaire or study. Surveys were anonymous and were assigned unique ID codes for tracking purposes. Surveys sought to evaluate perceptions on access to and affordability of simulators, barriers to surgical skills training, effectiveness of the GlobalSurgBox in training surgical techniques, and perceived barriers to utilization of the GlobalSurgBox. Results were analyzed as

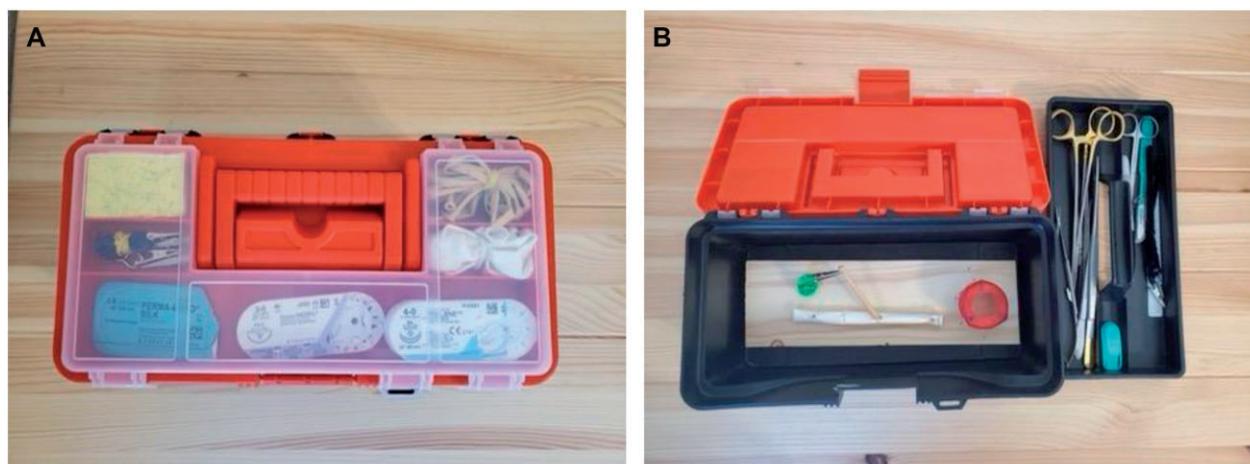


Figure 1. The GlobalSurgBox surgical simulator. (A) The lid contains important materials for practice including suture, balloons for anastomosis, rubber bands, alligator clips with pipe cleaners for holding ties, needle sponge, and extra fishing line for tying practice. (B) Toolbox includes surgical instruments, tools for knot-tying simulation, and the wooden board template on which to conduct simulation skills.

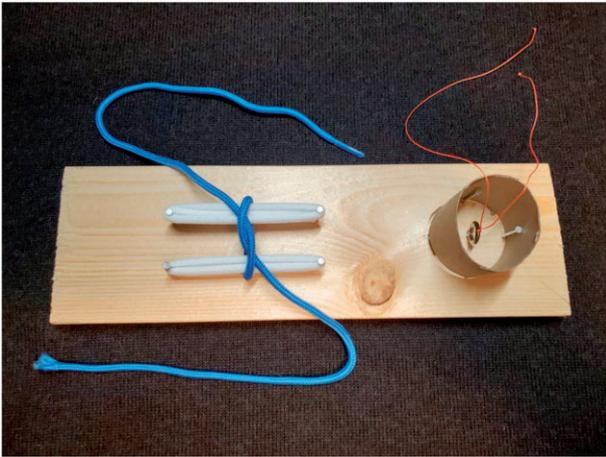


Figure 2. The GlobalSurgBox surgical simulator includes a wooden board that is modifiable for different skills. Shown is the template for knot-tying skills performance. On the left, hair ties and a shoelace are used to learn basic square-knot-tying skills. On the right, a cardboard tube is used around a screw eye nail with a fishing line to practice advanced 'deep cavity' knot tying.

percentages. This study was approved by the institution review board under COMIRB Protocol: 21-3402.

Results

Of the 45 students who attended the surgical skills training, 30 completed the post-event survey, representing a response rate of 67%. Of these, 20 were first-year medical students, nine were second-year medical students and one was a third-year medical student. Twenty-three students (77%) reported a lack of access to surgical simulation tools, four students (13%) reported access to a personal simulator, one student (3%) had access to a simulation center through a residency program and two students (7%) had access to a suture kit (Fig. 3). The results from students reporting access to surgical simulators ($n = 4$) have been negated given the low number of participants and the inability to draw any conclusions on current student practice with simulators.

Students were asked to self-rate their comfort level when using surgical instruments and performing different surgical skills before and after the training event. Respondents had to rate their level of comfort using the Likert scale (1 = no comfort, 2 = minimal comfort, 3 = neutral, 4 = somewhat comfortable, and 5 = very comfortable). There was a statistical difference between the comfort level of using forceps pre-training (mean = 2.7) and post-training (mean = 3.2) ($P = 0.02$). Alternatively, there was no statistical difference between pre- and post-training comfort levels for using

Medical student access to surgical simulation tools

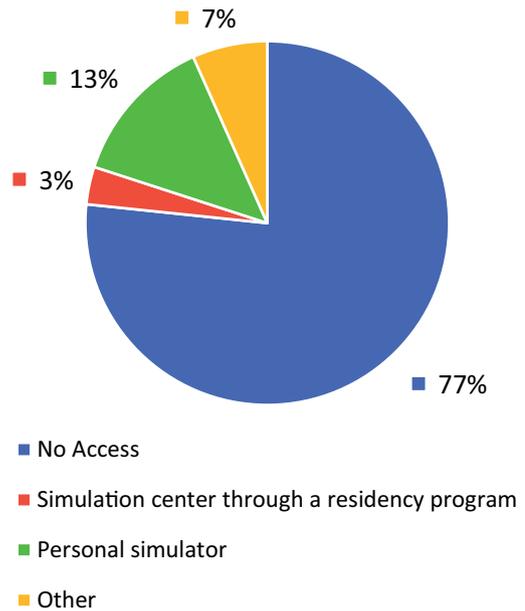
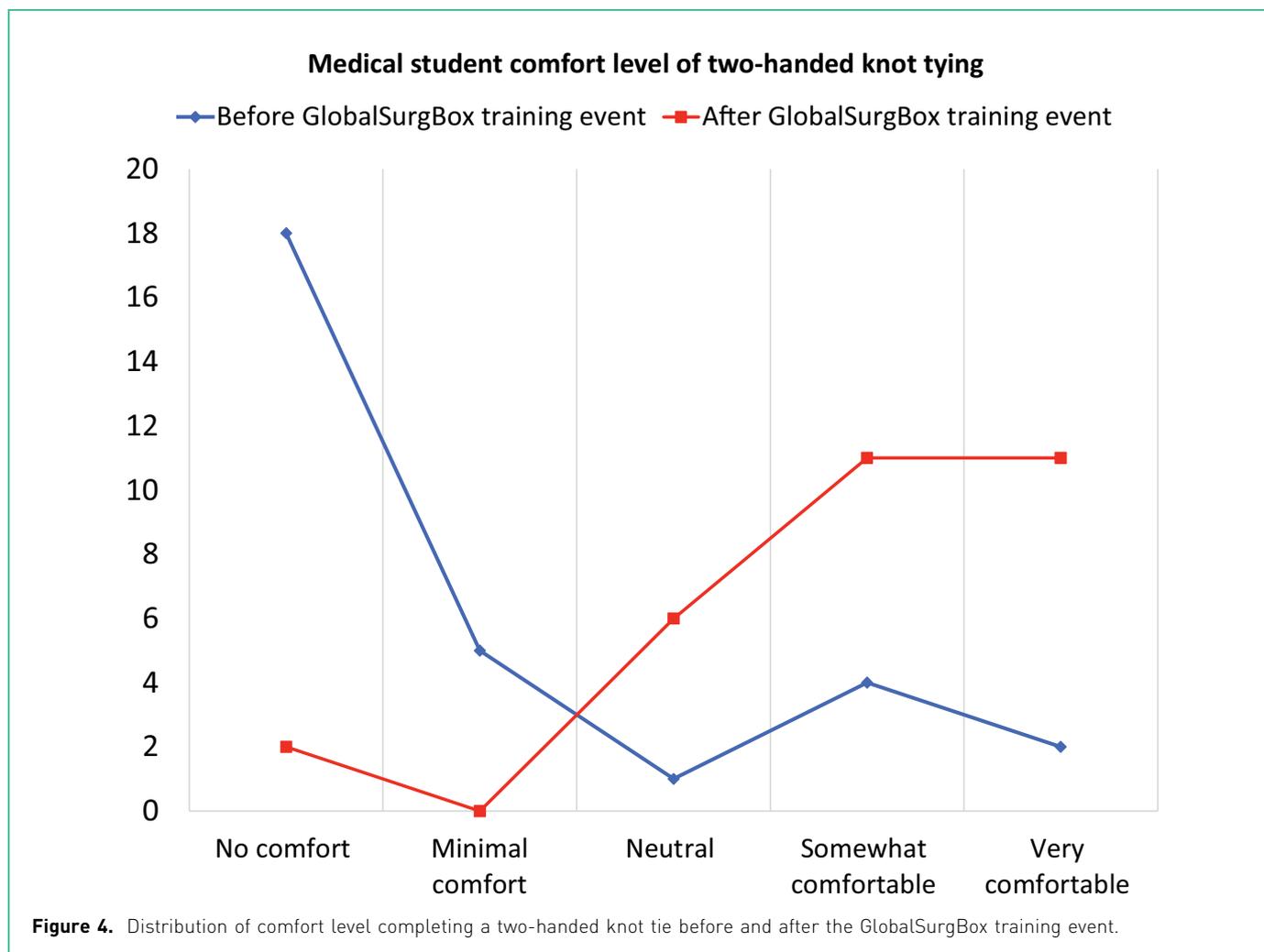


Figure 3. Students' responses to the question, 'Which surgical simulation tools do you currently have access to (not including the GlobalSurgBox)?'

needle drivers (mean = 2.3, mean = 3.3, respectively) ($P = 0.61$) and one-handed knot tying (mean = 2.0, mean = 4.1, respectively) ($P = 0.13$). Meanwhile, the reported comfort level of pre-training two-handed knot tying (mean = 1.9) compared to post-training (mean = 4.0), showed a statistically significant increase in comfort level ($P = 0.03$) (Fig. 4). Lastly, the evaluation of the pre- and post-training comfort levels of suturing (mean = 1.8, mean = 3.5, respectively) revealed a significant increase ($P = 0.04$) in the comfort of learners after a single exposure to the GlobalSurgBox simulator (Fig. 5).

Twenty-three trainees (77%) strongly agreed that surgical simulation was helpful for their surgical training. Twenty-four learners (80%) strongly agreed that the use of the GlobalSurgBox encouraged further practice of surgical skills and 16 learners (53%) felt more prepared to enter the operating room than before use of the trainer. The simulator was deemed modifiable to meet advanced training needs by 20 of the learners (67%). When asked what additional obstacles would prevent students from using the GlobalSurgBox, if they owned one, the most common response was lack of available personnel to coach them through the simulation (43%), followed by lack of time (32%). Only one student reported personal lack of enthusiasm as an obstacle (3%), while five students (14%)



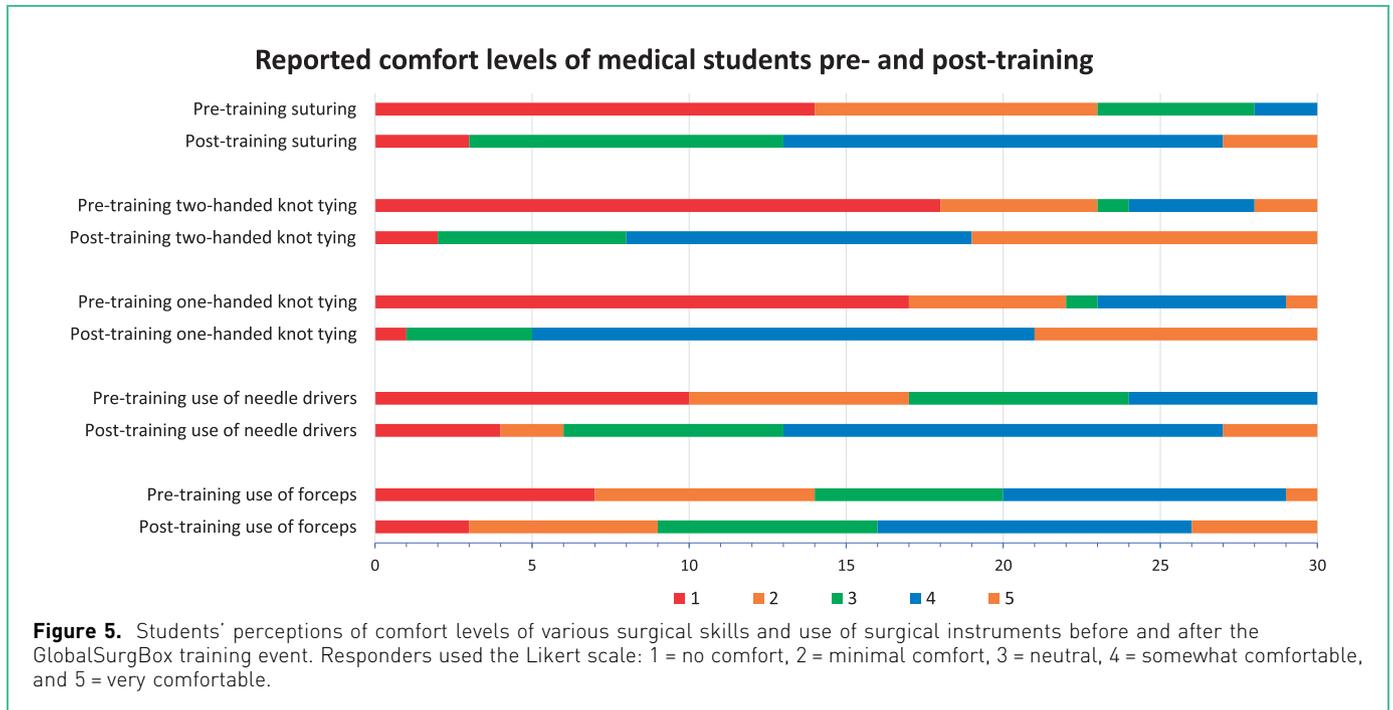
reported no barriers to using the trainer. Students indicated a mean price of US $\$33.7 \pm 10.20$ for the amount that they would be willing to pay for a single GlobalSurgBox trainer.

Discussion

Our results suggest that the majority of medical student trainees lack access to surgical simulation tools, despite stating that this was useful for their training. For students with access to a personal simulator, there appears to be a wide variability in personal out-of-pocket expense (US $\$35.0 \pm 40.9$) for each student; however, this result is limited by a low number of reports and participants. Our results also show that a short simulation training session can significantly improve the reported comfort level of trainees in handling surgical instruments as well as performing basic surgical skills.

Simulation training is an integral component of many high-reliability industries, including aviation and military, as it

provides a safe avenue for learning skills in a stepwise progression with demonstration of competency. Surgical training programs have also adopted simulation for similar purposes, and it has become standard for residency training programs to incorporate or offer simulation training to residents as a part of its curriculum. However, the same is not true for many medical students and their medical schools. Medical students often must instead rely on clerkship orientations, weekend bootcamps, student interest group events, and self-directed learning to learn basic introductory surgical skills. Our study demonstrated that many students (57% of medical students who already had access to a simulator) purchase their own personal simulators for practice—these represent low-fidelity simulators intended for basic skills training such as knot tying and suturing. While low-fidelity surgical simulators may be less realistic than a true operating room experience compared to their high-fidelity counterparts, they offer a lower financial barrier to access, and often utilize materials which are either reusable or can be



easily replaced. Despite this, additional barriers may still exist, including the fact that each simulator may focus on only a limited set of skills. The GlobalSurgBox was created with all these barriers in mind, in an attempt to eliminate as many barriers as possible to increase opportunities for practice. We then utilized the GlobalSurgBox to facilitate an in-person training event for medical student trainees.

The GlobalSurgBox is a compact and portable simulator that contains all the necessary instruments and materials needed to design and complete a variety of surgical skills modules. This design allows users to practice in any setting and enables simulation exercises to be set up and practiced in a reasonable amount of time, further increasing the likelihood of its use. The GlobalSurgBox is also unique in that it is modular, adapting to users' needs over time. Flexibility of design and selection of materials provided allows learners to create modules appropriate for medical student trainees, as well as higher-level learners such as residents, fellows, and surgical faculty. In addition, every GlobalSurgBox includes access to instructional aids for module setup and virtual instruction of skills, hosted at www.GlobalSurgBox.com. As an additional benefit, the GlobalSurgBox, in conjunction with its online resources, represents a global health equity initiative. Each purchase of a GlobalSurgBox is matched with a donation box, carried by visiting surgeons biannually

to reduce cost of transportation, to partnering surgical training programs in low- and middle-income countries.

Our results demonstrate that after viewing instructional videos on medical student modules, and participating in directed learning using the GlobalSurgBox, medical students reported a significant increase in comfort when using surgical instruments including forceps and needle drivers, as well as when performing surgical skills including one-handed and two-handed knot tying. Participants also reported an increase in their comfort level of suturing after the event. Post-event reports indicate that students continue to cite lack of available training personnel/coaching, and lack of time as perceived barriers to ongoing use of the GlobalSurgBox. There is, however, an increase in the percentage of students who cite no foreseeable barriers to its use after participation in the event. Additionally, learners agreed that the GlobalSurgBox was modifiable to meet advancing training needs. Students further indicated a mean price of US $\$33.7 \pm 10.2$ for the amount that they would be willing to pay for a single GlobalSurgBox trainer—a price which aligns well with the cost to produce a GlobalSurgBox (approximately US \$25). Most medical students strongly agreed that the use of the GlobalSurgBox encouraged further practice of surgical skills and, most importantly, made them feel more prepared to enter the

operating room. These results collectively support the use of the GlobalSurgBox trainer in a hands-on training event as an effective method for the introduction of surgical skills to medical students.

There are a few notable limitations to this study. This study assessed participants' perceptions via a voluntary survey format. The overall number of students involved in the training session was low, and 67% of the attendees completed the survey, which significantly limits the validity of the conclusions drawn and weakens the power of the study. As with any survey, there is a risk that participants provide inaccurate responses or feel uncomfortable being associated with specific responses. There is also a risk that there are differences in interpretation of questions posed, and that participants cannot fully convey the depth of their perceptions given a limited selection of responses to each question. In addition, it is well documented that learners' self-perception of surgical skills development does not accurately reflect objective level of skills.¹³ Medical students involved in this study were volunteer participants, many of whom have expressed interest in surgery. Participants may, therefore, have been more likely to respond favorably to the use of the GlobalSurgBox, introducing selection bias. These limitations were minimized by allowing participants to provide responses anonymously, and by maintaining a consistent Likert scale for response options where appropriate. Additionally, while students did report that the use of the GlobalSurgBox encouraged further practice of surgical skills and made them feel more prepared to enter the operating room, we cannot conclude that the GlobalSurgBox was independently responsible for this outcome when additional factors, including hands-on instruction and allowance of dedicated time for practice, may have contributed. Nevertheless, our survey questions most often assessed participants' perceptions with respect to the GlobalSurgBox alone, and our study results strongly support the conclusion that the GlobalSurgBox had an overall positive impact on medical student trainees.

An additional limitation of this study is the duration and method of survey. This study is a single-center study that utilizes a single post-intervention questionnaire to assess user-reported perceptions on experiences and skills when utilizing the GlobalSurgBox in a single training event. There was no utilization of a pre-intervention baseline questionnaire, nor has any intermediate- or long-term follow-up survey been performed to assess the longevity of intervention benefits. These follow-up surveys represent one possible direction for future study. The methods of this study limit generalizability of results, and do not provide insight into the long-term impacts of our intervention. Separate studies

are also warranted to investigate the true utility of GlobalSurgBox for independent learning outside the context of a training event, while utilizing resources available at www.GlobalSurgBox.com. Follow-up with study participants who received the GlobalSurgBox can provide further insights into its use over time, with stratified analysis based on instructor and resource availability as well as training setting. Additionally, a more comprehensive study which compares the value of the GlobalSurgBox, to those offered by other popular simulators, is needed to better characterize the relative value of the GlobalSurgBox.

Conclusion

The GlobalSurgBox is a novel resource suitable for medical student trainees to supplement their education and prepare for their operating room experiences. The GlobalSurgBox aims to address several of the existing barriers to routine use of low-fidelity surgical simulators by medical students and offers students an affordable and modifiable means through which to learn basic skills, and subsequently advance learning in a stepwise progression.

The GlobalSurgBox, when utilized by medical students in the setting of video and hands-on instructional training, is a valuable resource for training introductory surgical skills techniques. According to medical students' perceptions, the GlobalSurgBox increases comfort with surgical tools and techniques and prepares students to enter the operating room. Though limited by lack of in-person instruction outside of training events, the GlobalSurgBox is seen as a more affordable and modifiable simulation trainer to other trainers utilized by students, thereby reducing barriers to use. The GlobalSurgBox is a useful tool for preclinical medical students for simulation training of surgical skills.

Conflict of interest

None declared.

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Appendix 1. Survey questions provided to participants

1. Please type in the first three letters of the city you were born in followed by the first three numbers of your major childhood street address. Surveys will remain completely anonymous, but unique ID codes will track participants' views over time.

2. What is your current level of training?

- Medical Student
- Resident
- Fellow

3. Please state your year in medical school:

- MS1
- MS2
- MS3
- MS4

4. Please state your post-graduate year:

5. What country are you currently training in?

6. Which surgical simulation tools do you currently have access to (not including the GlobalSurgBox)? Please select all that apply:

- I do not have access to any surgical simulators
- Simulation center through a residency program
- Personal simulator
- Other—please specify

7. What type of personal simulator do you currently own? Please select all that apply:

- Skin closure
- Knot tying
- Other—please specify

8. How are you able to get the materials for your simulator?

- Purchase them on my own
- Collect them from operating room/wards
- Receive them from my program
- Other—please specify

9. In total, approximately how much did you pay (in U.S. dollars) for all your surgical simulators and materials?

10. What are the most significant barriers to using the surgical simulators you currently have access to? Please select all that apply:

- Lack of convenient access to the trainer/would prefer to practice in a different setting (e.g. at home)
- Too expensive to purchase/gain access to a simulator
- Lack of available personnel to coach me through the simulation
- Personal lack of enthusiasm for using the trainer
- Lack of time
- No barriers, I use these resources routinely

11. Which exercise did you perform on the GlobalSurgBox? Please select all that apply:

- Knot tying
- Suturing
- Vascular (end to end)
- CABG—proximal (end to side)
- CABG—distal (end to side)
- Other—please specify

12. How many times have you used the GlobalSurgBox to practice the aforementioned skills?

- 1–2
- 3–4
- 5 or more

13. I was satisfied with the training event:

- Strongly agree
- Somewhat agree
- Neither agree nor disagree
- Somewhat disagree
- Strongly disagree

14. The GlobalSurgBox has enhanced my knowledge of surgical instruments:

- Strongly agree
- Somewhat agree
- Neither agree nor disagree
- Somewhat disagree
- Strongly disagree

15. The GlobalSurgBox has enhanced my knowledge of surgical techniques:

- Strongly agree

- Somewhat agree
- Neither agree nor disagree
- Somewhat disagree
- Strongly disagree

16. Surgical simulation is helpful to my surgical training:

- Strongly agree
- Somewhat agree
- Neither agree nor disagree
- Somewhat disagree
- Strongly disagree

17. The GlobalSurgBox is a good replica of the operating room experience:

- Strongly agree
- Somewhat agree
- Neither agree nor disagree
- Somewhat disagree
- Strongly disagree

18. I feel more prepared to practice in the operating room after using the GlobalSurgBox:

- Strongly agree
- Somewhat agree
- Neither agree nor disagree
- Somewhat disagree
- Strongly disagree

19. The GlobalSurgBox encourages more practice:

- Strongly agree
- Somewhat agree
- Neither agree nor disagree
- Somewhat disagree
- Strongly disagree

20. The GlobalSurgBox can be modified to meet my training needs as I advance my skills:

- Strongly agree
- Somewhat agree
- Neither agree nor disagree
- Somewhat disagree
- Strongly disagree

21. Compared to my personal simulator, the GlobalSurgBox is more easily modified to meet my training needs as I advance my skills:

- Strongly agree
- Somewhat agree

- Neither agree nor disagree
- Somewhat disagree
- Strongly disagree

22. Please rate your comfort level with using the forceps before the GlobalSurgBox training event:

- No comfort
- Minimal comfort
- Neutral
- Somewhat comfortable
- Very comfortable

23. Please rate your comfort level with using needle drivers before the GlobalSurgBox training event:

- No comfort
- Minimal comfort
- Neutral
- Somewhat comfortable
- Very comfortable

24. Please rate your comfort level with one-handed knot tying before the GlobalSurgBox training event:

- No comfort
- Minimal comfort
- Neutral
- Somewhat comfortable
- Very comfortable

25. Please rate your comfort level with two-handed knot tying before the GlobalSurgBox training event:

- No comfort
- Minimal comfort
- Neutral
- Somewhat comfortable
- Very comfortable

26. Please rate your comfort level with suturing before the GlobalSurgBox training event:

- No comfort
- Minimal comfort
- Neutral
- Somewhat comfortable
- Very comfortable

27. Please rate your comfort level with using the forceps after the GlobalSurgBox training event:

- No comfort

- Minimal comfort
- Neutral
- Somewhat comfortable
- Very comfortable

28. Please rate your comfort level with using needle drivers after the GlobalSurgBox training event:

- No comfort
- Minimal comfort
- Neutral
- Somewhat comfortable
- Very comfortable

29. Please rate your comfort level with one-handed knot tying after the GlobalSurgBox training event:

- No comfort
- Minimal comfort
- Neutral
- Somewhat comfortable
- Very comfortable

30. Please rate your comfort level with two-handed knot tying after the GlobalSurgBox training event:

- No comfort
- Minimal comfort
- Neutral
- Somewhat comfortable
- Very comfortable

31. Please rate your comfort level with suturing after the GlobalSurgBox training event:

- No comfort
- Minimal comfort
- Neutral
- Somewhat comfortable
- Very comfortable

32. If you owned a GlobalSurgBox, which of the following would be obstacles to using it? Please select all that apply:

- Lack of convenient access to the trainer/would prefer to practice in a different setting
- Too expensive to purchase/gain access (GlobalSurgBox will likely cost \$25–\$50)
- Lack of available personnel to coach me through the simulation
- Personal lack of enthusiasm for using the trainer
- Lack of time
- No barriers

33. The GlobalSurgBox will likely cost between \$25 and \$50. What is the maximum amount you would pay for this trainer?

34. Please provide additional comments or suggestions about your experience using the GlobalSurgBox: