Simulation training in cesarean delivery

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Surgical training has always been an essential element of obstetrics. Skills acquisition for cesarean delivery relies heavily on apprenticeship-style training, with a notable paucity of formal simulation training before taking an active role in surgery. Patient safety is compromised when surgeons possess poor surgical skills and inadequate knowledge to handle acute emergencies. Experience comes with "real-world" exposure or can be obtained in a simulated setting, where scenarios can be practiced without the risk of patient harm. As part of a larger Intensive Course in Obstetric Emergencies, a systematic and standardized 1-day simulation-based training for cesarean delivery was formulated and conducted. Our multimodal curriculum includes online precourse lectures and video resources combined with on-site skills training with simulated scenarios and workshops for core and complex skills. The curriculum emphasizes presurgical planning, the execution of quick appropriate maneuvers, anticipation of complications, and effective management of complications. Simulation training includes surgical emergencies, such as skin and uterine incisions, difficult fetal extraction, and management of hysterotomy extensions. Postpartum hemorrhage management is practiced, including compression sutures, pelvic devascularization, resuscitative hysterotomy, placental complications, and cesarean hysterectomy. Simulation is performed using equipment of varying fidelity, along with our training manual. A standardized curriculum that leverages adult learning theory, combined with rapid feedback to learners serves as the backbone of the course, ensuring consistency and quality. Although high-fidelity equipment enhances curriculum delivery, it is not an absolute necessity. Equipment mobility must be considered when conducting training in multiple regions. The training experience and outcome across 3 different countries, Malaysia, Thailand and Japan, were described and compared. Analysis of pre- and postskills test scores demonstrated improvement in all 6 cesarean skills tested across all groups. Our curriculum proved effective in terms of practicality, adaptability, and cost. The training is reproducible and modifiable for learners in different countries. Moreover, surgeons in attendance of the course valued the training experience.

Key words: adult learning, bladder injury, breech, B-Lynch suture, Burns-Marshall, C-Celia, cesarean surgical skills training, classical incision, complex cesarean, consent, cost-effective training module, De Lee, distance learning, exteriorization of uterus, fetal malpresentation, Google Classroom, hand prolapse, impacted fetal head, internal iliac ligation, Joel-Cohen, knitted uterine model, language adaptability, Lovset maneuver, Mauriceau-Smellie-Veit, multiple pregnancy, nontechnical skill, obesity, obstetrical leadership, Obstetric Phantom Set, ovarian artery ligation, Patwardhan, Pfannenstiel, placenta accreta spectrum disorder, placenta previa, prematurity, pull and push technique, robotic-based simulation, safe cesarean, second-stage cesarean, SimMom, simulation center, simulation training, skin incision, surgical skills assessment, transverse lie, uterine artery ligation, uterine compression suture, uterine fibroid, uterine incision, uterine tears

Introduction

The increasing cesarean delivery (CD) rate[1] with concomitant decreasing number of births[2] worldwide poses a considerable effect on training opportunities for the junior and senior medical professionals alike.[1,3] This presents the challenge to rapidly and sufficiently train surgeons to safely meet the increasing demand.

Surgical training has long been an essential element of obstetrics. Medical advances and patient safety issues have placed restrictions on duty hours and, therefore, limit the total time performing surgery.[4] A training apprenticeship tradition of "see one, do one, teach one"[5] was first espoused in the 1890s by an American surgeon, William Halstead of Johns Hopkins Hospital. This model alone is now considered inadequate to ensure patient safety. Simulation training mitigates real or perceived risk of patient harm by a learner while providing a standardized, effective, and reproducible means to provide surgical skills training.[4,6] There is considerable variation in surgical techniques used during CD.[7] Although all obstetrical physicians should possess a baseline level of competency and skills for patient safety, training may also lack standardization in education.[8] This may lead some physicians to complete training without the requisite skills.

Complex cesarean delivery

CD is usually perceived as a routine and safe method of childbirth. However, in some instances, this surgical procedure can be technically difficult with consequent health hazards for both the mother and the fetus. Complex CD can be caused by difficult access to the lower segment, complicated fetal extraction, laceration, organ damage, and abnormal placentation.[9]

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We prefer the term "complex" rather than "difficult" as "difficult" has a negative connotation and "complex" implies an unexpected event that can occur during a CD. However, both terms are used interchangeably in describing a technically challenging CD.

Development of a multimodal training curriculum for cesarean delivery

Our team previously conducted a 2-day Intensive Course in Obstetric Emergencies (ICOE) in Malaysia and regionally since 2014.[10] This 2-day course has 24 skills, including maternal resuscitation, postpartum hemorrhage, eclampsia, assisted delivery, labor room emergencies, and CD. This course was conducted across 8 countries over 5 years, between 1 and 2 times a year in each country. The report on the 2-day, 24 skills courses over 5 years was published in 2020.[11]

Of the 24 skills stations of the ICOE, 3 covered CD, which seemed insufficient given the importance of the increasing CD rate. We observed that many trainees lacked fundamental and complex surgical skills needed to maintain patient safety. Informal feedback revealed that the content in the 3 stations was too dense and not optimally paced. Hence, we developed a new 9-station module for CD, utilizing and improvising upon equipment of varying fidelity to conduct a course that is reproducible and adaptable to junior and senior obstetricians. The new CD course was crafted to accommodate both junior and senior obstetricians but was targeted to teach complex surgical procedures to those who already possess basic surgical skills and who already perform CD. This course emphasizes individual skills training rather than team-based training. This expanded CD module, called the Masterclass in Complex Cesarean Delivery, was introduced in 2022 in Malaysia and the Asia-Pacific region. We have since conducted 9 courses, and we describe the curriculum and highlight our experiences in Malaysia, Thailand, and Japan in this review.

Learning objectives

There are multiple learning objectives for this course. Poor surgical skills could result in maternal and neonatal morbidities and mortalities.[12] In general, the highest risk of birth fractures and birth injury occurs when CDs are performed under time pressure, such as after unsuccessful attempts of a forceps or vacuum delivery.[13] Obstetrical emergencies can occur, and an instantaneous decision and maneuver may make a difference in outcome. Participants are made aware that experience comes with "real-world" exposure or can be obtained in a simulated setting, where scenarios can be practiced without the risk of patient harm. In this curriculum, we emphasize presurgical planning, appropriate performance of complex delivery maneuvers, and anticipation and management of complications.

Course design and program

The Handbook of Obstetric Emergencies,[14] short online lectures, and skills videos comprise resources provided to participants via Google Classroom, allowing access 2 weeks before the workshop to 1 week after the course. To ensure quality and consistency, trainers receive a trainer manual in which the teaching structure and the key learning points are standardized. The content attempts to realistically construct emergency scenarios. We acknowledge that some of the inherent stress that occurs during an actual emergency or individual nuances of hospital operating systems may not be present during simulation.

The CD simulation training is a 1-day onsite simulation workshop (Figure 1). It is limited to 24 participants, divided into 3 groups of 8 each. The intended participants are practicing obstetricians of any level of experience. Often, the literature emphasizes multiprofessional team-based simulation as the way forward.[15] However, we used an adaptive simulation training model based on individual needs and skills as a foundational first step. Having a presimulation understanding of the background of the physicians' skills, experience, and needs is essential.[16]

Lectures are made available online using the flipped classroom technique.[17] This incorporates precourse reading of materials and videos to enhance understanding of the surgical skills and specific scenarios that will be taught. This adult learning concept is student-centered, allowing flexibility of time to learn and optimizing better engagement with the trainers for onsite skills training. Lecture topics include essentials of CD, safe CD, documentation, how to provide informed consent, essential postoperative care, practical measures during transfer, abnormal presentations, and intrapartum maternal collapse.

For assessment, we relied upon the Bloom taxonomy,[18] which encompasses 3 domains of learning: cognitive, affective, and psychomotor (sensory) domains. In this course, we used 2 of 3 domains. The pre- and postcourse multiple-choice questions assessed the cognitive domain, whereas the skills evaluation formed the basis of the psychomotor domain. The multiple-choice questions are included in the Google Classroom. Participants are to complete the postcourse multiple-choice questions before receiving the certificate of attendance.

Simulation workshop

Simulation training consists of skills stations, which are described in detail below. Trained instructors demonstrate skills in adherence to the training manual and use the previously distributed videos as an additional resource. A range of equipment of varying fidelity and training tools are used for the training (Video 1).

Skin and uterine incisions

The learning outcomes for the participants are (1) to comprehend the different abdominal incisions for adequate exposure for multiple clinical scenarios and (2) to perform and appreciate adequate uterine incisions for difficult delivery and extension techniques.

Training equipment

The training equipment include the following: SimMom (Laerdal, Stavanger, Norway), Obstetric Phantom Set (Adam, Rouilly Limited, Sittingbourne, England, United Kingdom), fabric

FIGURE 1
Cesarean delivery training program

2 weeks before course:
Google classroom with lectures, multiple-choice questions and online Handbook sent to all participants

Start of 1 Day course:
Pre-skills tests (6 stations)
Incision, tears, compression suture, fetal malpresentation, pelvic devascularization and impacted head

Lecture: Evidence based interventions in reducing primary CD (15minutes)
Video: Obstetric leadership (15 minutes)

Breakouts
2 Trainers per workstation. Participants in 3 groups. Concurrent workstations with participants rotating after 30 minutes

Breakout 1 (30 minutes each workstation): total 90 minutes

Room	1	2	3
Skills	**Skin and Uterine incisions**	**Extended tears**	**Uterine compression sutures**

Feedback

Breakout 2 (30 minutes each workstation): total 90 minutes

Room	1	2	3
Skills	**Fetal malpresentations**	**Uncommon scenarios: fibroids, obese, twin, resuscitative hysterotomy**	**Impacted fetal head**

Breakout 3 (30 minutes each workstation) : total 90 minutes

Room	1	2	3
Scenario	**Pelvic devascularization**	**Placental problems**	**Cesarean hysterectomy**

Post-skills tests (same 6 stations)

Feedback and Close

Google form feedback and certification

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uterine models, Doyen abdominal retractor, inflated pink balloons, and surgical suturing pads.

Description

Adequate exposure is the key to safe surgery. The participants are taught various abdominal and uterine incisions. Each participant draws the incisions using marker pens.

The abdominal incisions simulated include the Joel-Cohen, Pfannenstiel, midline, and Maylard. The uterine incisions simulated are the low transverse incision, extended J, inverted T, De Lee, and classical (Figures 2—4). The indications for each are discussed.

Repair of extended uterine tears

The learning outcomes for the participants are (1) to be able to recognize, identify, and repair extended uterine tears and (2) to recognize and repair bladder tears.

Training equipment

The training equipment include the following: postpartum hemorrhage control trainer (C-Celia; 3B Scientific, Hamburg, Germany), SimMom or Obstetric Phantom Set, needle holder, Green-Armytage hemostatic forceps (Surgical Holdings, Southend-on-Sea, England, United Kingdom), retractors, and appropriate suture material.

Description

The uterine model has a lateral angle tear complete with torn vessels that can be made to "bleed" (Figure 5, A and B; Video 2). This uterine model is inserted into the SimMom, and participants are taught surgical principles in repair. If a high-fidelity uterine model is not available, a fabric uterine model with a precut angle can be used (Figure 5, C—E).

Simulation includes the use of appropriate long instruments, atraumatic uterine muscle clamps, retractors, and sutures. The method of identifying the narrowest point of the tear as the apex and placing the suture just distal to the apex is illustrated.

In addition, potential complications of bladder and bowel injuries are highlighted. Postrepair inspection and short-term management are discussed. If time is available, the trainer leads discussions on the postoperative care, team management, intensive care monitoring, and thromboembolism prophylaxis.

Uterine compression sutures (B-Lynch)

The learning outcomes for participants are (1) to be able to identify the anatomic landmarks and perform a B-Lynch suture for the management of postpartum hemorrhage during CD and (2) to comprehend other uterine compression sutures.

The training equipment include the following: appropriate surgical hand instruments, sutures and knitted uterine models (1 model to 1 participant). This knitted model is tailor-made for the authors (Figure 6, A and B). It is made of pink lightweight cotton material sourced locally. It is cotton lined internally to mimic the bulk and softness of the uterus. A zip opening is added to mimic the lower segment cesarean incision. Further additions are the colored knitting yarn to

FIGURE 2
Demonstration of abdominal wall incisions

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resemble uterine vessels and the ovaries. A softer version is used for compression sutures to allow threading of the needle.

Description

Each participant uses a 45-mm half-circle round-bodied 90-cm polyglactin absorbable suture to perform B-Lynch on the uterine model after a demonstration by the trainer (Figure 6, C and D). In addition, Hayman and Cho square compression sutures are demonstrated.

Fetal malpresentations

The learning outcomes for the participants are (1) to be able to perform fetal extraction techniques in breech, transverse lie, compound presentation, and hand prolapse with understanding of the risks of each move and (2) to comprehend and perform external and internal rotations with extension of uterine incisions when necessary.

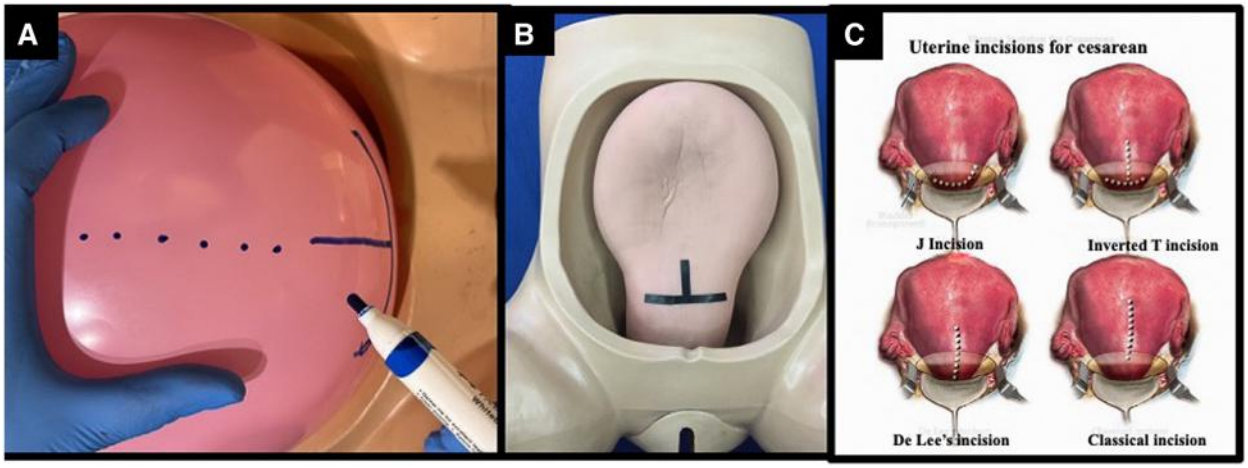
The training equipment include the following: C-Celia C-Section Fetal Extraction Trainer with a fetal doll (3B Scientific, Hamburg, Germany), gel, gloves, and an additional fetal doll for external demonstration.

Description

Fetal malpresentations during CD require special skills to safely deliver the fetus and to minimize maternal injuries. The malpresentations simulated on the C-Celia are breech, transverse lie (both dorsal superior and dorsal inferior), hand prolapse, and compound presentation (Figure 7, A).

The fetal doll is positioned in a breech presentation inside the C-Celia. The breech extraction technique is taught together with the Lovset maneuver to deliver the fetal shoulder, emphasizing on rotation and minimizing trauma and complications. The Mauriceau-Smellie-Veit technique is

FIGURE 3
Demonstration of uterine incisions



A, An inflated pink balloon mimics the pregnant uterus and is placed within the pelvic model. Uterine incisions and the methods of extension are simulated using a marker pen. **B,** Alternatively, the uterine incision and extension can be simulated on a silicone uterine model using a tape. **C,** Illustration of various types of uterine incisions taught during the simulation session, as seen in the handbook.

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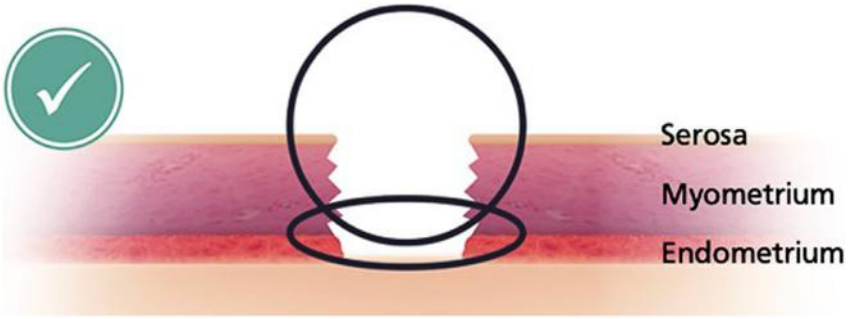
FIGURE 4
Illustration of uterine closure



Participants are encouraged to repair the uterine incision in 2 layers, as shown in this illustration from the handbook.

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taught to deliver the fetal head (Figure 7, B and C; Video 3).

Similarly, for transverse fetal presentation, external version techniques, uterine incision site, and identification of the fetal heel are taught. Standing on the contralateral side of the mother during CD is taught for ergometry of fetal extraction.

The technique to deliver hand prolapse and compound presentation is demonstrated. In addition, other surgical principles, such as optimizing uterine incisions, using uterine tocolytic agents, and using the other hand to stabilize the uterus are emphasized.

Impacted fetal head

The learning outcomes for the participants are to (1) comprehend and (2) perform the stepwise maneuvers for an impacted fetal head.

The Training equipment include the following: C-Celia C-Section Fetal Extraction Trainer with fetal dolls.

Description

The maternal and fetal implications of an impacted fetal head at CD are serious. Therefore, essential skills must be acquired by all physicians. The C-Celia is used to teach these skills, where participants can appreciate the abdominal opening and uterine incisions and deliver the fetus and placenta. The trainer demonstrates the delivery of an impacted fetal head with the following points: an assistant cups the fetal head from below, maternal positioning in both supine and Trendelenburg positions, avoidance of flexion of the fetal head, using the nondominant hand, delivery in between contractions, and optimizing uterine tocolytic agents. The push technique, the pull technique (Figure 8), and the Patwardhan technique are demonstrated, initially outside the abdomen to demonstrate and visualize the technique, followed by the "in utero" demonstration (Figure 9).

Systematic pelvic devascularization

The learning outcomes for the participants are (1) to accurately recognize in a stepwise fashion the uterine, ovarian, and internal iliac vessels and (2) to ligate these vessels.

The training equipment include the following: knitted uterine model, Obstetric Phantom Set or SimMom, surgical instruments and sutures, and Obstetric Phantom Set with internal addition of colored tubes to simulate the retroperitoneal structures. These additions are improvised by the authors.

Description

The improvised knitted uterine model simulating the ovarian and uterine vessels is used in this demonstration where it is inserted inside the Obstetric Phantom Set. In addition, the Obstetric Phantom Set has been improvised to simulate the broad ligament, ureter, and internal iliac vessels (Figure 10, A–C). Trainers demonstrate and participants practice the stepwise identification of the following vessels: the ovarian, uterine and internal iliac (Figure 10, D–F; Video 4), as a useful skill to control severe postpartum hemorrhage.

Placenta previa and placenta accreta spectrum disorder

The learning outcomes for the participants are (1) to understand the importance of preoperative planning and multimodal management, (2) to deliver the fetus safely in anterior previa, and (3) to suture placental bed bleeding.

The training equipment include the following: SimMom or Obstetric Phantom Set, placenta model, knitted uterine model, suturing pad, surgical instruments, and appropriate-sized suture.

Description

Abnormal placental conditions are known to pose serious morbidity if the physician is inadequately skilled. Here, the participants are taught using a knitted uterine model where the placenta is inserted into the uterine model. The uterine model is placed in the pelvic model and simulated to show anterior previa major (Figure 11, A) and the steps to carefully deliver the fetus with the placenta obstructing access. A suture pad is placed inside the uterine model to simulate bleeding placental bed varices, and participants are taught hemostatic sutures (Figure 11, B). Other principles emphasized are the use of tranexamic acid, hemostatic gels, and meticulous preoperative planning.

The placenta accreta spectrum disorder (PASD) is discussed as an interactive whiteboard teaching, eliciting the principles of a safe outcome.

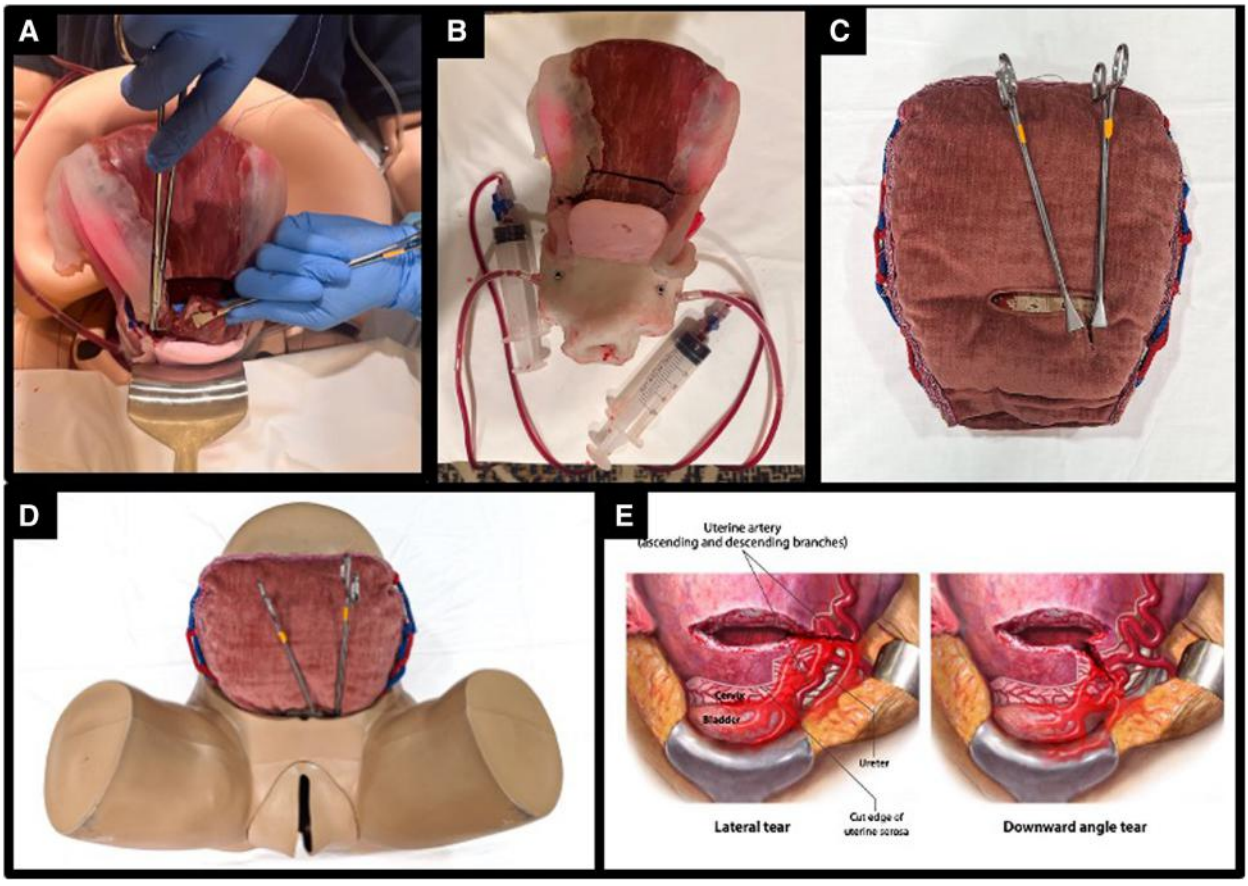
This station does not include a learner performance assessment.

Cesarean hysterectomy

The learning outcomes for the participants are (1) to comprehend that cesarean hysterectomy is a high-risk surgery requiring multimodal management and senior staff involvement and (2) to know the steps of this surgery.

The training equipment include the following: knitted uterine model

FIGURE 5
Demonstration of extended uterine tears



A, Simulation of lateral uterine angle tear, complete with torn vessels in a uterine model and placed in the SimMom model. The use of appropriate surgical instruments, abdominal retractors and exteriorization of the uterus are emphasized. **B,** The torn vessels can be simulated to bleed with the use of syringes filled with red-colored dye. **C,** Alternatively, a low-fidelity fabric uterine model with a precut uterine angle tear can be used. The image shows the use of 2 pairs of Green-Armytage hemostatic forceps to secure the lateral angle tear. **D,** The fabric uterine model can be inserted into the pelvic model, and exteriorization is shown to aid repair. **E,** Participants are reminded to be cautious of the adjacent anatomy and are shown the involvement of the uterine vessels in lateral and downward angle tears, as illustrated in the handbook.

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complete with uterine and ovarian vessels placed in an Obstetric Phantom Set, long needle holder, 1/0 absorbable suture, scissors, 2 Zeppelin curved forceps, 2 Zeppelin straight forceps, and a Doyen retractor.

Description.

The steps of a hysterectomy are demonstrated on the model with the aid of PowerPoint slides as an added resource (Figure 12). Discussions involve the following: prophylactic salpingectomy, subtotal hysterectomy, usage of intraoperative tranexamic acid, hemostatic agents, massive transfusion protocol, abdominopelvic drains, abdominal packing, and methylene blue bladder integrity test. In addition, Enhanced Recovery After Surgery, high dependency care, consent, documentation, and counseling are highlighted.

This station does not have a learner performance assessment.

Uncommon scenarios

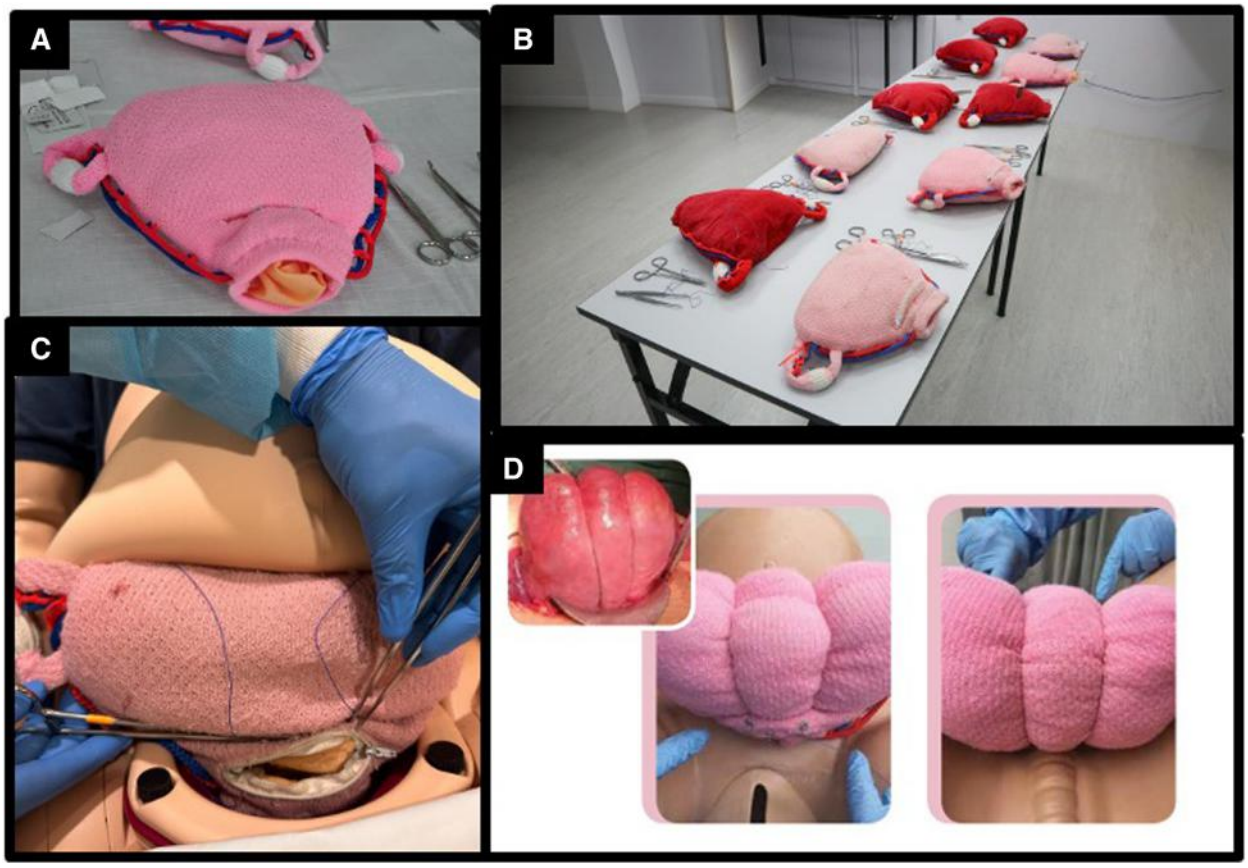
The learning outcomes for the participants are to know and manage intricate real-world scenarios with CD.

The training equipment include the following: video recording of thick abdominal wall entry, resuscitative hysterotomy tray, Wrigley forceps, ventouse cup, small balloon in a fabric uterine model (Figure 13, A), and 2 fetal dolls in a pelvic model.

Description

Participants are invited to pose scenarios to the trainers involving complex conditions that they have encountered. This training style promotes engagement and helps understand participants' needs. If the participation is not forthcoming, the trainer will demonstrate several complex

FIGURE 6
Demonstration of uterine compression sutures



A, The uterus used for simulation is a pink cotton-knitted model complete with a zip opening to mimic the lower segment uterine incision and colored knitting yarn to resemble the uterine vessels and ovaries. **B,** The participants practice in a workstation with 1 uterine model per participant, complete with surgical instruments and sutures. **C,** Simulation is performed by placing the uterine model inside a SimMom pelvis, with participants performing the steps of B-Lynch sutures. **D,** The simulated end result is compared with that of a real B-Lynch suture, as illustrated in the handbook.

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procedures as time permits, including resuscitative hysterotomy (Figure 13, B), handling prematurity, lower segment uterine fibroids, multiple pregnancies, obesity, multiple surgical skin incisions, instrumental delivery for CD, and bladder injury.

This station does not have a learner performance assessment.

Learner assessment

On the day of the on-site workshop, the participants are assessed on skills immediately before and after the program (pre- and postskills tests). The skills are tested in the Objective Structured Clinical Examination[19] format, assessed by 1 trainer per skill. Each skill test lasts 2 minutes, marked on a standardized checklist with the total score per test being 10. The participants are scored 1 point for each correctly performed substep in a station. The participants are scored zero points if they omit or perform the substep incorrectly. The participants are not prompted or allowed to have another attempt and instead the trainer quickly moves to the next substep.

We assessed 6 of 9 most commonly used skills because of time and resource constraints. PASDs and cesarean hysterectomy were demonstrated, and participants were allowed to practice surgical steps and were invited to pose questions about other uncommon scenarios that they had encountered.

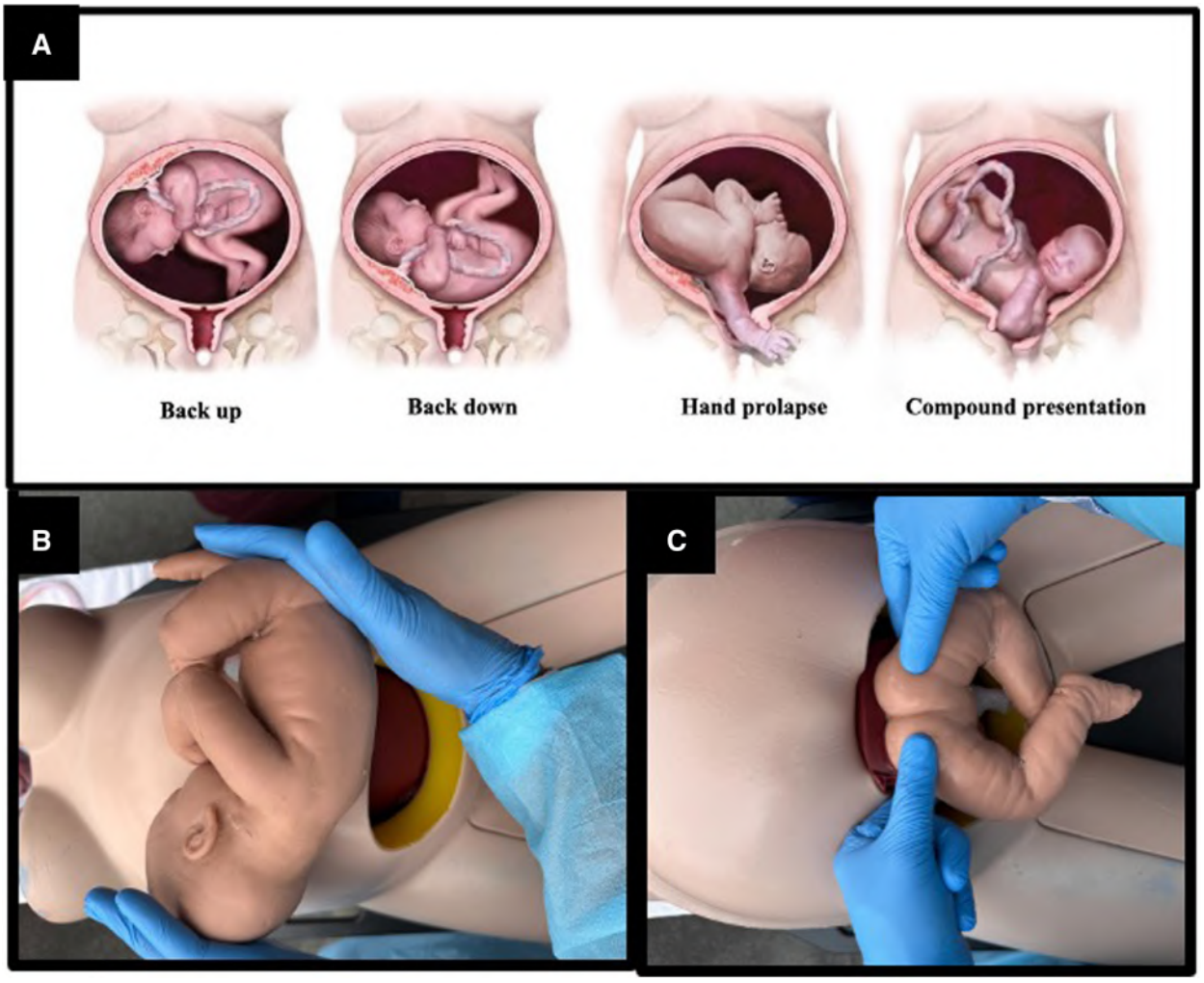
The scoring schemes of the 6 skills are presented in Tables 1 to 6.

Course evaluation

The data presented below are from the 1 course each, conducted in Japan, Thailand, and Malaysia. There were a total of 65 participants, of whom 16 were from Japan, 22 were from Thailand, and 27 were from Malaysia. The participants were of mixed experience. The results presented in the tables below are the comparison of pre- and postskills scores.

Statistical analyses were performed using GraphPad Prism 8 (GraphPad Software, Boston, MA).The data were

FIGURE 7
Demonstration of fetal malpresentations



A, Participants are shown in transverse lie, dorsal superior and dorsal inferior, hand prolapse, and compound presentations, as illustrated in the handbook. **B,** The simulation of the rotation of a transverse lie dorsal inferior presentation is demonstrated outside the uterus initially, and participants practice the rotation inside the C-Celia pelvic model. **C,** Participants are trained to perform breech extraction in the C-Celia model.

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statistically analyzed using paired *t* test to compare differences between countries and between pre- and postskills scores of the 6 skills. A probability value of $<.05$ was considered statistically significant (which is indicated with an asterisk).

Skills improvement

In Japan, Thailand, and Malaysia, all participants showed a significant improvement in all 6 skills after the course (Figure 14). This applies to the 6 skills and the overall score for all skills combined. However, the percentage increase differs for the various skills among the groups, depending on the complexity and the experience of the participants (Figure 15). Studies have concurred with our findings of possible improvement in skills after simulation training for CD.[20]

Skills with high preskills score and potential for improvement

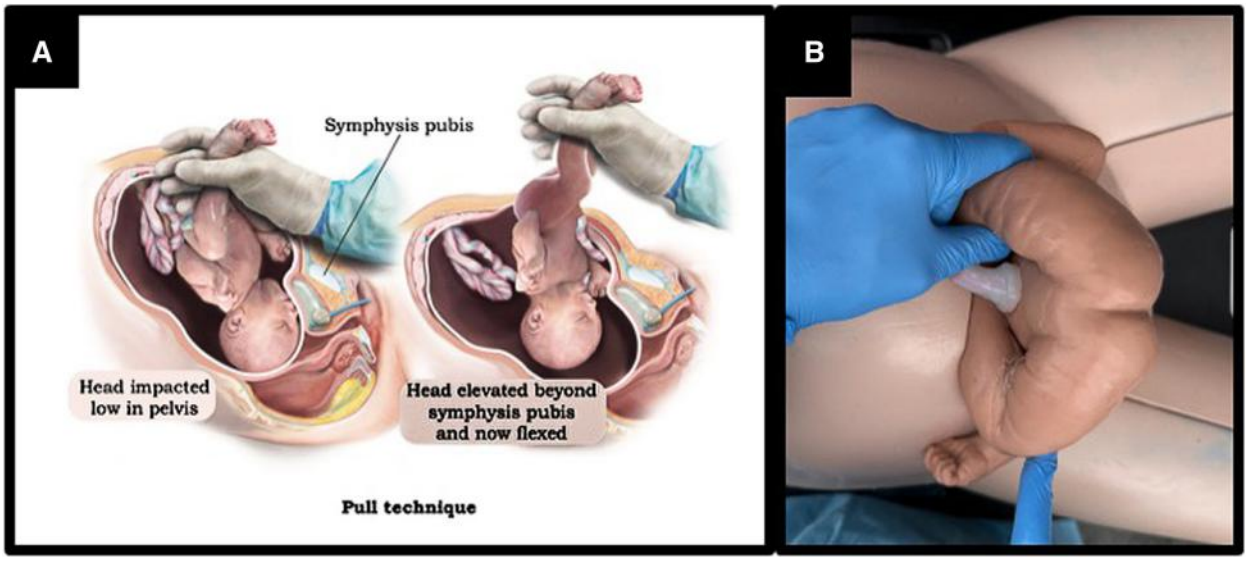
Uterine tear

The participants from Japan obtained high preskills scores, suggesting that the participants may have a strong foundation. However, similar to the other groups, the participants still demonstrated improvement after the course. This shows that physicians can still benefit from simulation-based training for refining cesarean skills.

Fetal malpresentation

Difficulty in delivering a fetus in malpresentation is often the cause of fetal injury.[21] Once more, the participants in Japan obtained high preskills scores. However, significant improvement was noticeable in the postskills scores, highlighting the importance of training in complex CD.

FIGURE 8
Demonstration of the pull technique



A, The trainer demonstrates the methods of disimpacting the fetal head, including the pull technique, as illustrated in the handbook. **B,** The pull technique is simulated using a C-Celia pelvic model, where the fetus is delivered as a breech.

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Compression sutures

All groups displayed high preskills scores, suggesting existing surgical competence. Nevertheless, improvement was noted in the postskills scores, reinforcing the importance of skills training in surgical management of postpartum hemorrhage.[22] The improvised low-fidelity model was shown to be applicable and able to simulate this skill.

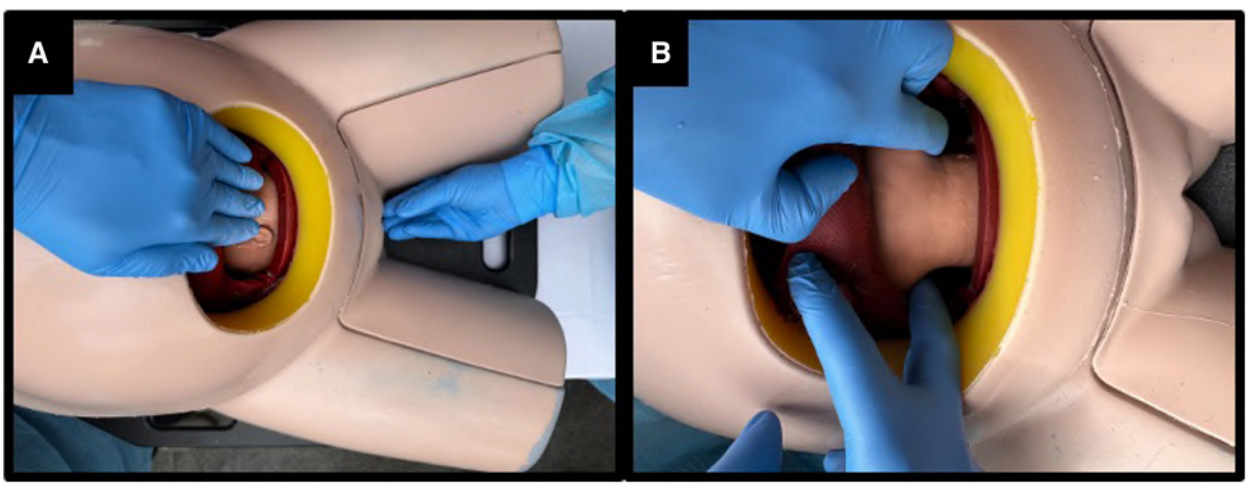
This station can benefit from further highlights on uterine compression suturing techniques, such as Hayman et al[23] and Cho et al.[24]

Skills with low preskills scores showing the greatest improvement

Skin and uterine incisions

Surprisingly, all groups had low preskills scores in this fundamental skill. However, the program resulted in increased scores exceeding 50%. This underscores

FIGURE 9
Demonstration of the push technique



A, The push technique is simulated in a C-Celia model. Vaginal disimpaction by the assistant together with abdominal disimpaction by the surgeon using the nondominant hand. **B,** Alternatively, the fetal shoulder can be disengaged by the surgeon using both hands.

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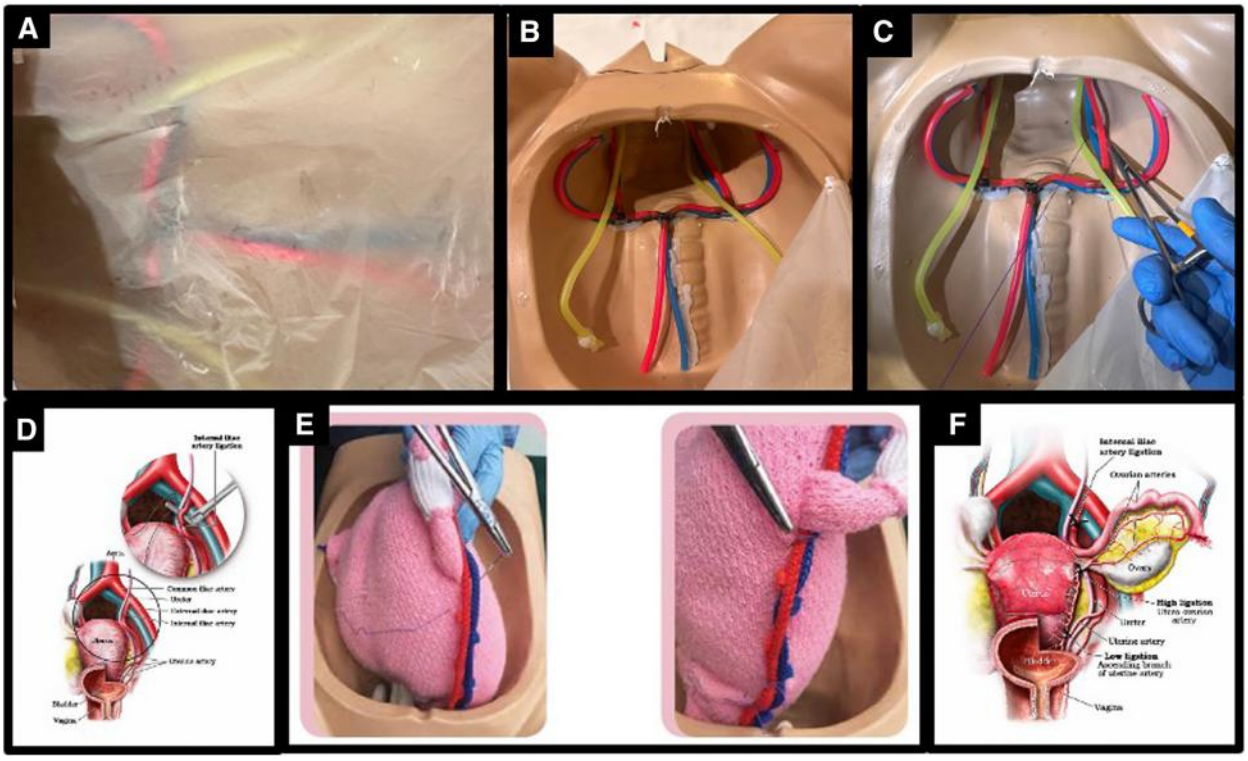
FIGURE 10
Demonstration of systematic pelvic devascularization



A, The Obstetric Phantom pelvic model is improvised with transparent wrapping plastic sheet to simulate pelvic peritoneum. **B,** The Obstetric Phantom pelvic model is improvised to demonstrate retroperitoneal structures beneath the plastic sheet (peritoneum). Colored tubes are affixed to the model to show major pelvic blood vessels (*red/blue*) and the ureter (*yellow*). **C,** Participants are trained to isolate the internal iliac artery and to place the right-angle forceps below the internal iliac artery 2 to 3 cm below the bifurcation. **D,** Placement of the right-angle forceps, as illustrated in the handbook. **E,** Simulation of ligating the ovarian vessel is demonstrated on a soft fabric-knitted uterine model, using a stitch and tie, inferior to the ovarian ligament. **F,** Ligation of the uterine artery, utero-ovarian artery, and internal iliac artery in systematic pelvic devascularization, as illustrated in the handbook.

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the need for training for basic procedures in all participating groups.

Impacted fetal head

Participants from Japan had the lowest preskills score, which may mean lower exposure to this skill. However, the participants achieved significant improvement after training. With an incidence of 1 in 10 emergency CDs for an impacted fetal head,[25] it is important that the physicians are skilled in the push and pull techniques and other options. Repeated simulation with team-based practice may improve the outcome[26,27] and address skill gaps.

Systematic pelvic devascularization.

Malaysian participants had the lowest preskills and poor skills score for this advanced procedure. However, all groups showed significant improvement. We used a low-fidelity pelvic model and improvised with anatomic markings and colored tubes as vessels and the ureter. This stepwise vessel ligation skill, although more intricate, should be taught to all physicians.[28]

The current data are underpowered, and the participants had varying levels of experience, which made data interpretation difficult. The results exhibited a mix of percentage improvement, regardless of seniority and country.[29] We tried to be objective in the assessment of skills. However, long term outcome data that accounts for participant experience and patient outcomes are yet to be evaluated. The long-term goal would be to achieve certification and recredentialing by the relevant professional institutions.

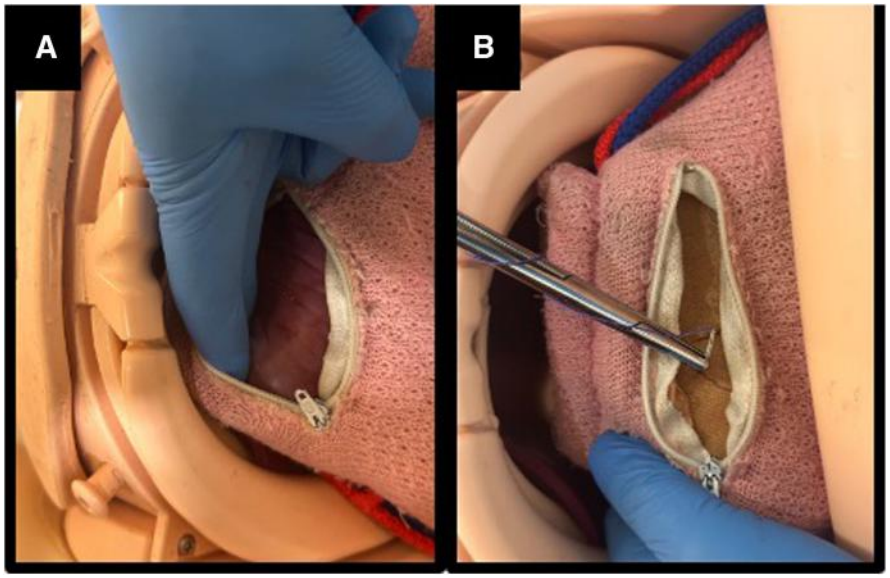
Lessons learned

Skills not assessed

The teaching of PASD is an interactive guided simulation session that adds a different flavor to the teaching methodology. We realized that this style of group teaching fostered interaction with participants sharing experiences. Although the participants were aware of management guidelines,[30,31] there was little training on the surgical skills of managing PASD during CD.[32,33] This station gave it a more real-world perspective. The participants shared positive feedback on the suturing aspect of the placental bed using the simulated models.

Cesarean hysterectomy is a technically difficult surgical procedure because of the altered anatomy and increased blood supply in a pregnant mother.[34] However,

FIGURE 11
Demonstration of placenta previa simulation



A, The anterior placenta previa is simulated using a knitted uterine model inserted into the pelvic model. The placental model is inserted into the uterine model anteriorly, and participants are taught how to use the hands to negotiate the anterior previa to deliver the fetus. **B,** A suturing pad is placed posteriorly inside the knitted uterine model to simulate bleeding placental bed varices. Participants are taught the application of hemostatic sutures on the bleeding placental bed.

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the lack of surgical confidence due to the lack of skills could well deter a physician from performing the procedure.[35] The steps of this lifesaving procedure were shown using a low-fidelity pelvic model with an improvised knitted uterus.[36] This generated a lot of enthusiasm as it is seldom taught.

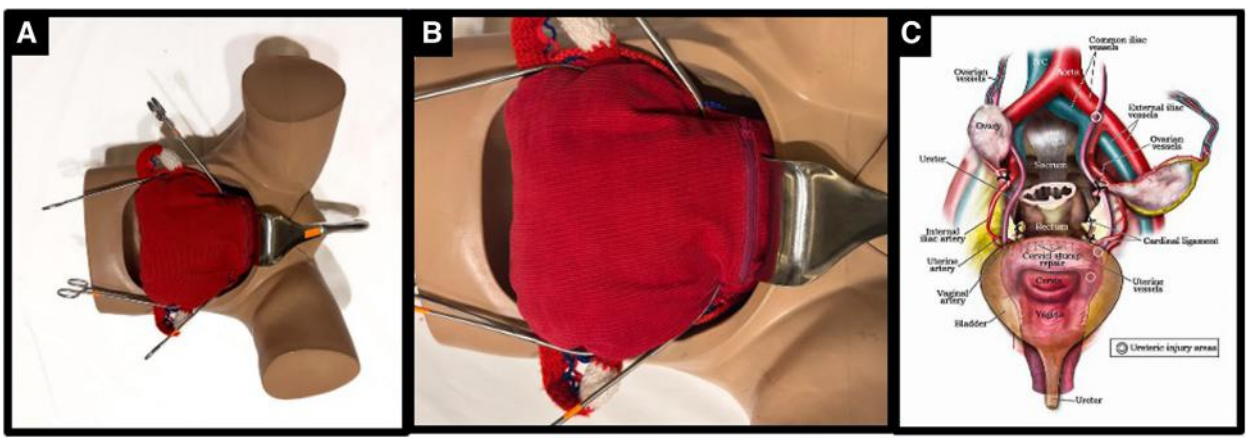
Uncommon scenarios are seldom taught and are understandably difficult to demonstrate, even in apprenticeship training. The incorporation of intricate scenarios enabled the participants to discuss and engage with trainers to demonstrate real-world conditions that the participants would have encountered. Besides being knowledgeable in these complex conditions presenting during a CD, this session fostered an enjoyable interactive 2-way learning experience. We learned that this creates a more engaging, positive training environment.

The training requirements of the physicians

The Malaysian group showed a larger percentage increase in postskills scores in uterine tears and systematic pelvic devascularization (Figure 15). However, the participants performed better in the preskills tests in incisions and impacted fetal head. Interestingly, these are the same 4 skills that show opposite results for Japan.

We can infer that having a pre-simulation understanding of the background of the physicians' skills,

FIGURE 12
Demonstration of cesarean hysterectomy



A, Simulation is performed using a fabric uterine model placed in the Obstetric Phantom Set. Participants are taught essentials: adequate exposure, use of the Doyen retractor, exteriorization of the uterus, and appropriate surgical clamps. **B,** Demonstration of medial application of surgical clamps on ligaments and uterine vessels. **C,** Common sites for ureteric injury during hysterectomy are highlighted, as illustrated in the handbook.

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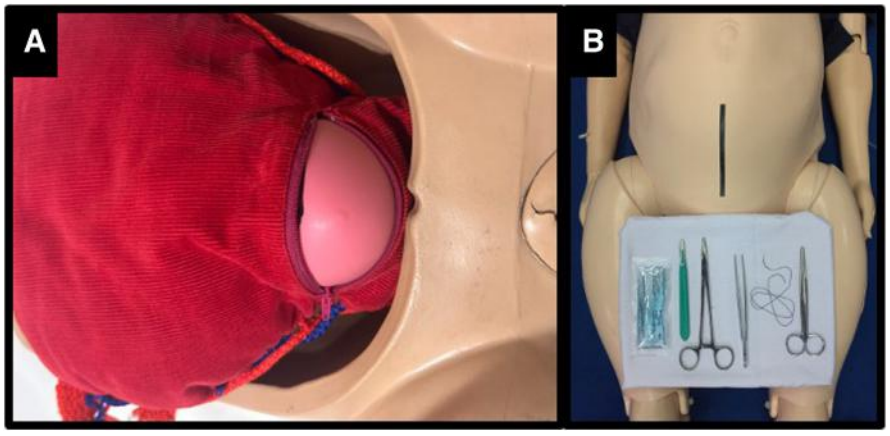
FIGURE 13
Demonstration of complex scenarios



A, A small inflated pink balloon is inserted in a fabric uterus, simulating a fibroid in the lower uterine segment. Participants are taught techniques to overcome this difficult entry. **B,** Resuscitative hysterotomy is simulated on the SimMom model. A midline incision is mimicked using tape, and participants are shown the steps in using minimal surgical instruments.

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experience, and needs is helpful. Participants have varying levels of baseline skill, and training modules must adapt to satisfy these diverse needs.[4] In addition, this is likely a reflection of the objectivity of the surgical skills assessment.[37] All participants, regardless of training, demonstrated improvement in at least 1 skill, which shows that this course and its teaching methodology are relevant and effective for mixed grades of physicians performing CD. The demonstration of uncommon emergency CD skills provides an opportunity to practice rare, high-risk scenarios and crystallize important steps, thereby improving upon any previous skills.

Training equipment

Equipment plays an important part in simulation training, and the lack thereof can affect skills acquisition in CD. In addition, this is found in studies related to an impacted fetal head, which shows skills are lacking due to training and lack of equipment.[26,38,39] High-fidelity simulation with the appropriate equipment has been shown to produce the most effective form of training.[40] However, our experience shows that a low-fidelity model, such as the knitted uterus, is still effective in

TABLE 1
Incision assessment sheet

No	Incision	Give 1 point for each step performed correctly	Action by participant
1	Joel-Cohen	2	Identifies landmarks • Anterior superior iliac spine • 3 cm below and straight line
2	Pfannenstiel	1	2 cm above symphysis pubis and curvilinear line
3	De Lee	1	Lower vertical incision in the uterus above the uterovesical fold
4	Low transverse	3	• Correct dextrorotation of the uterus and identify the lower segment • Reflect the uterovesical peritoneum • Make a small incision in the uterus and extend the incision laterally by using the fingers
5	Classical incision	3	• Correct the dextrorotation and identify the upper segment • Make a small incision in the uterus above the uterovesical fold and protect the neonate part with the nondominant hand • Cut with scissors, stopping short of the fundus, and 3-layer closure
	Total score	10	

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TABLE 2
Uterine tears assessment sheet

No	Tears	Give 1 point for each step performed correctly	Action by participant
1	Left uterine angle tear	5	• Exteriorize the uterus and use the Doyen retractor • Use Green-Armytage clamps at bleeding points • Identify and clamp the apex of the tear • Nondominant hand behind the uterus to protect • Apply 2/0 suture at the lowest possible apex point of the tear
2	Vertical inferior tear	5	• Exteriorize the uterus • Use Green-Armytage clamps at bleeding points • Identify and clamp the apex of the tear and suture • Apply the suture at the visible tear and pull until the apex is reached • Check bladder integrity using methylene blue dye test
	Total score	10	

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teaching the skills for B-Lynch compression sutures, implying that not all skills require high-fidelity equipment. Moreover, fidelity is affected by the scenario, trainers' performance, and feedback.

Creatively modifying various models based on available resources enhances the effect of teaching, even for complex skills, such as cesarean hysterectomy and systematic pelvic devascularization.[41] Although we have adapted and innovated on various models of different fidelity often based on resources, no single model is perfect.

The C-Celia is a high-fidelity mobile pelvic model with a realistic internal feel, helpful for demonstrating fetal extraction (Figures 16, A and B). The bulky SimMom is used in Malaysia and other centers for maternal resuscitation and hysterotomy, allowing the lithotomy position. It allows the demonstration of fetal disimpaction and extended tear repairs. The Obstetric Phantom Set permits the removal of the abdominal wall to show internal maneuvers (Figures 16, C–E).[42]

Adaptability of equipment

To conduct this course, several uterus and fetal models of varying fidelity are required (Figure 17). Most training venues do not have their simulation centers. Therefore, high-fidelity training is difficult to achieve. For the centers that do not possess some of the equipment, we air transport it for the courses. We transport models from venue to venue.

TABLE 3
B-Lynch assessment sheet

No	Step	Give 1 point for each step performed correctly	Action by participant
1	Type of suture used	1	Large curved absorbable needle size 1
2	Step 1	2	• Placement of suture 3 cm medial and below the lower segment uterine incision • Thread suture 3 cm above and pass over the fundus
3	Step 2	3	• Reenter uterine cavity • Pass suture horizontally • Exit uterine cavity posteriorly on the contralateral side
4	Step 3	4	• Pass suture posteriorly over the fundus • Thread suture through the upper and lower edges • Compress the uterus and tie a knot • Assistant to compress the uterus
	Total score	10	

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TABLE 4
Fetal malpresentation assessment sheet

No	Malpresentation	Give 1 point for each step performed correctly	Action by participant
1	Flexed breech during cesarean delivery	3	• Identify the foot and buttocks • Lovset maneuver • Head: Burns-Marshall technique or Mauriceau-Smellie-Veit
2	Transverse lie with fetal back down	3	• Stabilize and push the fetus to breech position • Without rupture of membranes, identify the foot and bring it to the longitudinal lie • Use the other hand to push the head to the longitudinal lie and deliver as breech
3	Hand presentation	4	• Cusp fetal head with dominant hand • Move fetal head to uterine incision • Deliver the fetal head • Nondominant hand to flex the impacted shoulder
	Total	10	

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Therefore, we opt for mobile lightweight equipment, such as fabric uteruses. Some equipment, such as the surgical instruments, are heavy. Occasionally, we will use the local center's instruments.

Lack of equipment has inspired and encouraged the local organizers to engage stakeholders to buy in and relevant agencies to seek funding to develop a skills lab and acquire more appropriate training equipment.[43] The training mannequins can be of mixed fidelity, and some can be improvised. These strategies will enhance smart partnerships in training to not only use funding to maximum benefit but also create a cost-effective module tailored to individual center's needs.

Adaptability in scope: stand-alone stations

Recognizing that training centers may be limited by equipment and time for training, we believe that any of the 9 workstations can be used as a single stand-alone focused skills training. This allows for more time to be spent in training with adequate feedback and is

TABLE 5
Impacted fetal head assessment sheet

No	Technique	Give 1 point for each step performed correctly	Action by participant
1	Position of the patient	1	Lithotomy
2	Uterine incision	1	Higher and wider
3	Dislodging the impacted fetal head	1	Demonstrate how the assistant should push the head from the vagina with cupped hands
4	Push technique	3	• Disengage the fetal head from the pelvis while maintaining flexion of the head • Disengage the fetal shoulder with the nondominant hand • Deliver the head from the abdominal cavity
5	Pull technique	3	• Dominant hand to reach for fetal feet in the uterine fundus and grasp both feet together • Deliver the feet through the uterine incision • Deliver as breech extraction
6	Fetal pillow	1	Trainer to ask question on other techniques available
	Total score	10	

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TABLE 6
Pelvic devascularization assessment sheet

No	Vessel ligation	Give 1 point for each step performed correctly	Action by participant
1	Uterine artery ligation	4	• Exteriorize the uterus • Use 1/0 absorbable suture and identify the uterine vessels in the broad ligament • Place sutures distal to the tear • Place the next suture proximal to the tear
2	Ovarian artery ligation	2	• Partially rotate the uterus and identify the ovarian vessels • Use 1/0 absorbable suture and place the suture below the ovarian ligament
3	Internal iliac artery ligation	4	• Open the retroperitoneum in the pelvic sidewall and identify the common iliac vessels and internal iliac at the pelvic brim • Care to avoid the ureter • Use of right-angle forceps to place the suture in the internal iliac artery • Check femoral pulse before closing
	Total score	10	

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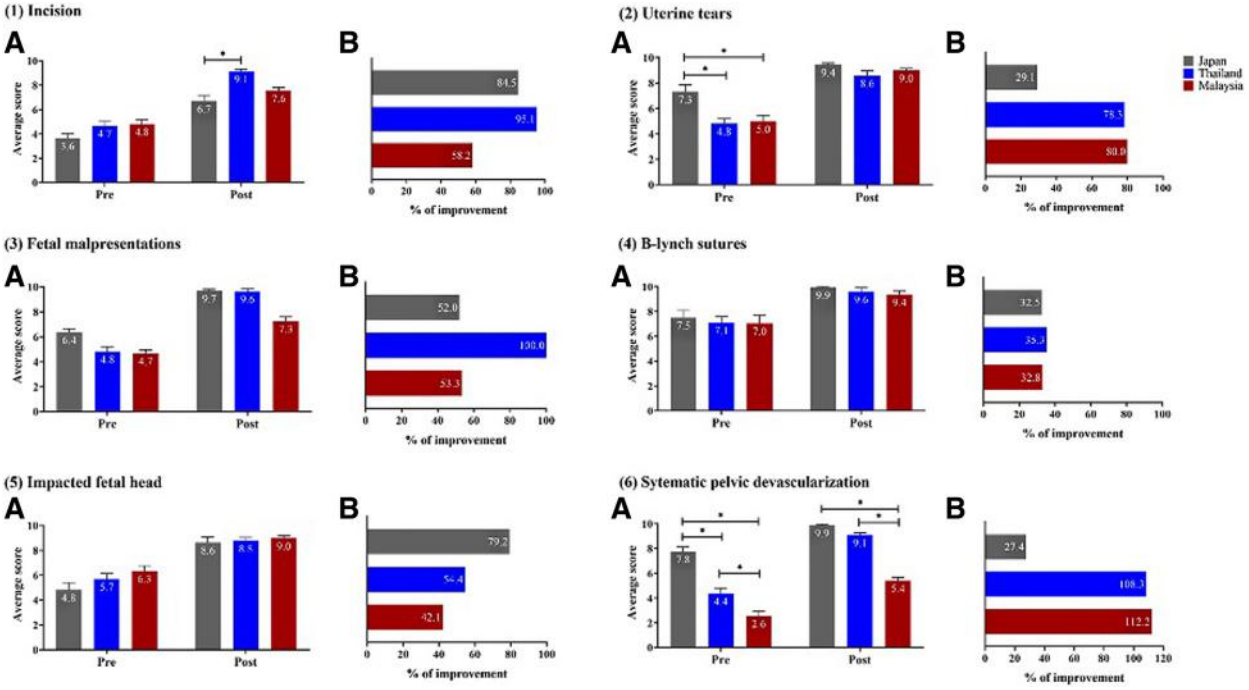
more targeted to the needs of the center.

Our opinion is that the workstations can be grouped as competency sets. The beginner set can be one of "challenges in access," and here, the skills will be skin and uterine incisions and extended tears. Placental problems can be combined with cesarean hysterectomy and difficult scenario as advanced skills. A mixed competency set can be (1) fetal malpresentations and an impacted fetal head

FIGURE 14
Pre- and postskills test results with percentage improvement



The *gray bar* indicates Japan, the *blue bar* indicates Thailand, and the *red bar* indicates Malaysia. **P* value of <.05.

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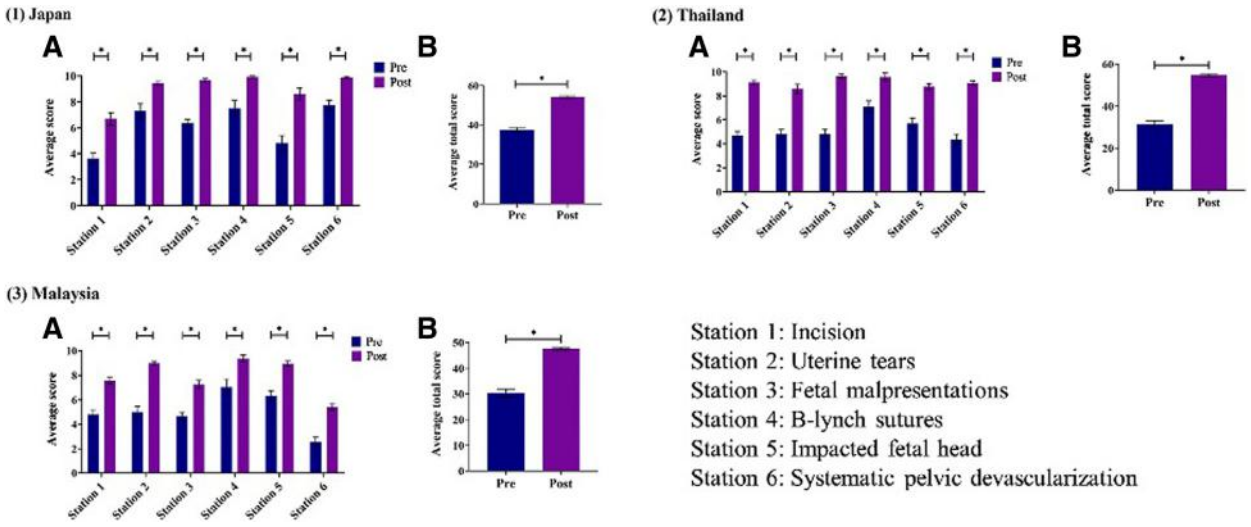
FIGURE 15
Pre- and postskills test results for each and overall skills



The average scores of pre- and postskills test results (**A**) and the percentage of improvement of scores (**B**) for incision (1), uterine tears (2), fetal malpresentations (3), B-Lynch sutures (4), impacted fetal head (5), and systematic pelvic devascularization (6) in Japan, Thailand, and Malaysia. **P* value of $<.05$.

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themed as "difficult fetal extraction" and (2) uterine compression sutures and pelvic devascularization as "surgical treatment of postpartum hemorrhage."

Adaptability in language

The course was conducted in English in Malaysia. However, some degree of translation was supported by the local faculty in Japan and Thailand. This training bundle demonstrated that the training is seamlessly adaptive across different linguistic contexts, with participants showing improved scores. Our experience shows that simulation skills training transcends language barriers as it is less verbal and more demonstrative.

The key to overcome communication and language gaps is to design a course based on a simplified language, emphasizing visual aids, optimizing model fidelity, focusing on hands-on skills, and often optimizing bilingual facilitators and translators. Appreciating cultural sensitivities, having a pretraining engagement, and allowing peer training among the delegates are effective measures not only in overcoming communication barriers but also in making learning impactful.

Feedback

Feedback is an essential part of our simulation training and has always been appreciated by the participants.[44] The feedback received from the participants is that the course defines the steps clearly on the skills when faced with a complex CD. We suggest that simulation-based training should allow sufficient time for feedback as this guides learning direction and promotes active and reflective learning. It provides opportunity to reemphasize key learning points apart from enhancing communication between the trainer and the participants.

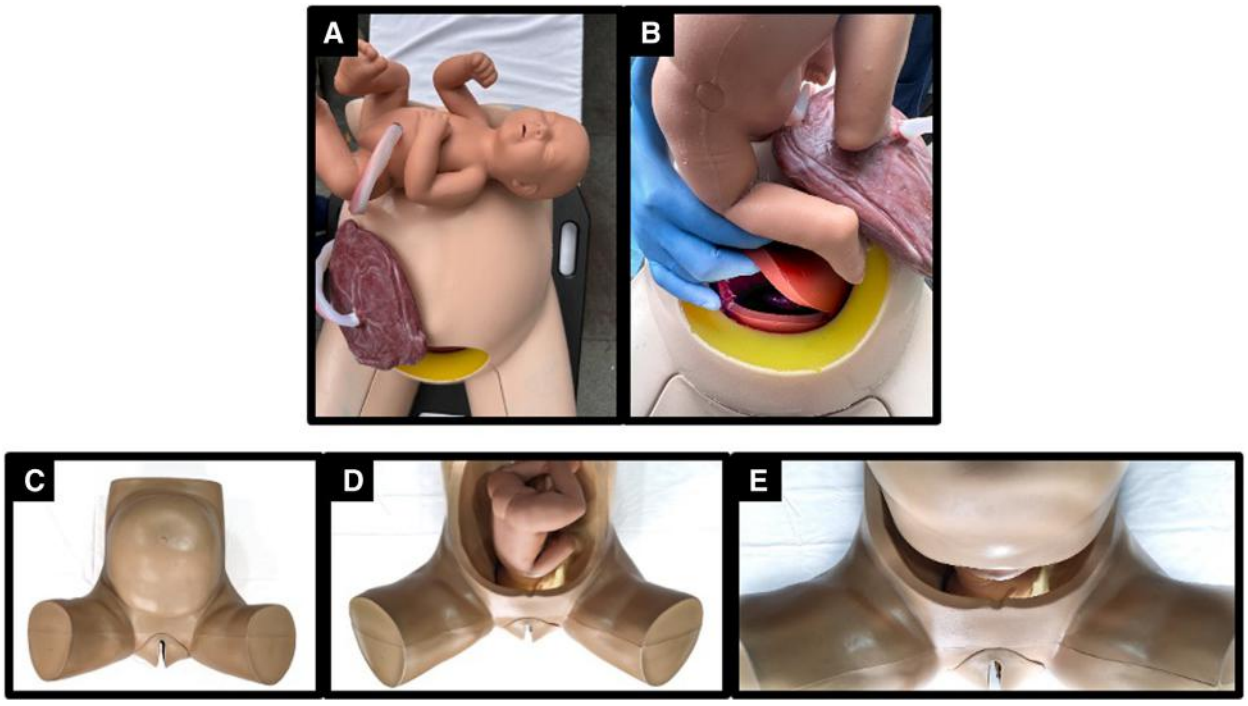
Financial framework

The financial model when we conduct the training overseas is a shared undertaking. We rent the equipment at no fee, and the trainers use their personal baggage allowance to airfreight the 120 kg of equipment. There is no royalty fee for the training curriculum as we believe no physician should be deprived of skills and knowledge when caring for the pregnant mother. The host society covers the cost of faculty accommodation, transportation, and venue. The participants pay a nominal registration fee and $35 (US dollars) for the handbook.[14] The total training cost is estimated at around $5000 per course. This is likely an underestimate as it does not quantify for hidden costs, such as administrative support, allowances, utilities, disposables, and insurance. The cost of these mixed fidelity simulation equipment is high, and any training center must factor the economic viability of such training. The average cost of equipment varies between countries and the type of fidelity. A high-fidelity model, such as SimMom, may average $100,000, whereas C-Celia may average $20,000. A medium fidelity, such as Obstetric Phantom Set, may average $2000. Use of equipment that is part of an established simulation center may offset some of the cost, as the equipment can be used several times, maximizing value. Private and public partnership may create means to develop patient safety courses further.[45]

Distance learning

We have challenged conventional teaching methods to address inequalities in access to education, resources, and training. We have had experience in our distance teaching where we piloted a

FIGURE 16
Training equipment of various fidelity



A and B, The C-Celia is a heavy, high-fidelity obstetrical training model that realistically simulates complex cesarean and fetal malpresentations. **C, D, and E,** The Obstetric Phantom Set with a detachable abdominal skin allows insertion of a fetal doll for cesarean delivery simulation. It is moderate fidelity, mobile, and low-weight model.

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remote-based simulation training for uterine balloon tamponade. Of note, 1 group had on-site training, whereas the other group had remote learning. The results showed that the postskills scores were the same for both groups.[11] Our findings showed that distance learning is a viable option for selected skills.

Based on this experience, we hope to formulate a significant module for remote training for the skills related to basic and complex CDs, which we believe will be one of the solutions to improving maternal health from a global perspective.[46]

FIGURE 17
Various low fidelity and light weight knitted models

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Nontechnical skills

Although our training curriculum primarily teaches core and complex skills related to CD, we dedicated a substantial part of the course toward teaching nontechnical skills, especially the skills related to communication, leadership, decision-making, situational awareness, teamwork, and task management. We realized in our training that even experienced physicians are lacking in nontechnical skills, which are often not formally taught in the medical curriculum. The nontechnical skills for surgeons has been developed worldwide, and incorporation of this training is an essential component in training for patient safety.[47]

Structured surgical training

In all 3 centers, it was observed that structured training on surgical skills is lacking, which accounted for great enthusiasm from the participants who expressed a desire for additional time in the workstations.

As a historic part of the commonwealth, Malaysian participants have been exposed to British medical training. Unlike the Malaysian participants, the Thai and Japanese participants were not as exposed to similar medical training. There is less penetration by the Western training courses, and this is where this program was able to bridge the gap and allowed more equitable access to surgical training.[48]

Strengths and limitations

Our skills training was focused on physicians. Stratifying physicians by years of experience would have been useful data to collect to tailor the training to the need. Participants demonstrated enthusiasm for this course and for additional training. Barriers to broadening this workshop to additional attendees include cost and the need to balance time spent in training with direct patient care.[49] In addition, the training was unable to assess some of the skills. However, better models and more trainers may overcome this problem. Lack of appropriate fidelity equipment and simulation centers poses a challenge for upscaling training. In addition, the authors were unable to gather data on long-term patient outcomes in a real-world setting, which indicates an area of future study.

Shaping the future

Future directions include training multidisciplinary teams. The initial steps are underway to scale up the training. In addition, we have trained trainers in Japan and Thailand by conducting train-the-trainer courses. Hence, in the future, trainers will be able to conduct the course with minimal supervision, which will remain available only to ensure quality and standardization. We will identify "champions" who can inspire and pursue the training agenda locally. We believe that, in the future, rapidly advancing virtual telemedicine tools can be employed effectively to scale the courses.

Artificial intelligence, virtual reality, and robotic-based simulation are novel options for learning to be considered into the training bundle. This technology can be used to engineer realistic anatomic models and can be optimized to generate complex scenarios. These training approaches should not only be individualized but also be meaningful, cost-effective, and significant, especially when addressing the issues of inequality in training, education, and resources.

Conclusion

Training for CD is possible using simulation with mixed fidelity equipment. By focusing on the emergency skills needed for complex CD not usually taught by apprenticeship, it achieved a high level of improvement in postskills scores. It is effective in different countries and, therefore, proven reproducible. Our experience shows that the needs of the participants vary, and training modules must be adaptive, practical, and cost-effective to satisfy their expectations. For training sustainability and accessibility, it requires dedicated leadership and funding for a more widespread reach. ■

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