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Creation and Evaluation of a Cesarean Section Simulator Training Program for Novice Obstetric Surgeons

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Abstract

Background: We evaluated a novel simulation-based cesarean section training program to teach critical techniques for cesarean section and hemorrhage management.

Methods: This was a prospective educational intervention. After Institutional Review Board approval, we recruited Obstetrics and Gynecology, Family Medicine, and General Surgery residents at three hospitals. All participants received didactic education. Participants were then randomized into two arms with one group to receive task-trainer based training and the other no training. Afterwards, all residents had their performance of a complete cesarean section and management of a post-partum hemorrhage evaluated on a high-fidelity simulator. Evaluators were blinded to randomization.

Experience: Thirty-three participants were recruited between July 2017 and January 2019. There were 19 trainees in the control group and 14 in the intervention group. The intervention group scored significantly higher on performance of the cesarean delivery (p-value 0.007), hemorrhage management (p-value 0.0002), and overall skill (p-value 0.008). There were no differences in the other categories.

Conclusion: Participants trained with a combination of didactic education and task-trainers versus didactic education alone performed significantly better on all procedural aspects of a cesarean section and hemorrhage management on a high-fidelity simulator, demonstrating that simulation-based training allows trainees to gain procedural experience while decreasing patient risk.

Categories: Obstetrics/Gynecology
Keywords: simulation in medical education, simulation trainer, emergency and elective cesarean, postpartum hemorrhage, education and training of medical students and doctors (specialist and phd)), deployment medicine

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Introduction

Simulation has the potential to increase surgical skills and prepare physicians to perform complex tasks without risk to patients. Training using simulators has increasingly been incorporated into all aspects of obstetrics education. The Accreditation Council for Graduate Medical Education (ACGME) now requires simulation to be utilized in Obstetrics and Gynecology (OB/GYN) training programs [1]. In 2018, the American Board of Obstetrics and Gynecology made completion of the Fundamentals of Laparoscopic Surgery (FLS) program a prerequisite for the certifying examination [2,3]. Obstetric simulation demonstrates positive effects on clinical outcomes for shoulder dystocia, operative vaginal delivery, emergent cesarean delivery, postpartum hemorrhage, and can improve teamwork in response to obstetric emergencies [2-9]. Non-obstetricians may benefit from simulation training in the event they need to perform or assist in a cesarean section during a combat deployment, while on a humanitarian mission, or when stationed at a remote facility [10,11]. Simulation may also be useful in rural or low resource areas where an experienced OB/GYN may not be immediately available. As such, a high-fidelity cesarean section surgical simulator may have benefit when used as an adjunct to learn, practice, and reinforce obstetric surgical skills in a wide variety of settings.

Our objective was to evaluate the performance of a high-fidelity simulator program to train novice providers on cesarean delivery and post-partum hemorrhage management.

Materials And Methods

This study was a prospective educational intervention approved by the Institutional Review Boards from all institutions involved, conducted from July 2017 to January 2019. Residents from three separate military

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training hospitals were invited to participate by a study administrator who had no role in residency oversight or evaluation. The administrator obtained informed consent and allocated trainees to didactic versus didactic plus task trainer. We offered enrollment to all OB/GYN interns, Family Medicine senior residents, and General Surgery senior residents. Trainees were excluded if they previously served as primary surgeon for a cesarean section during their residency. This was a convenience sample, based on the total number of trainees available for participation.

All participants attended a standardized didactic lecture covering the indications for cesarean, procedural steps of the case, and medical and surgical postpartum hemorrhage management techniques. After the lecture, trainees were informed about whether they were allocated to the didactic education only versus didactic education plus task-trainer group. The task-trainer group underwent training with cesarean section task-specific simulators for the procedures of skin incision, uterine incision, delivery of the fetus, wound closure, and operative interventions for post-partum hemorrhage including placement of uterine compression sutures and repair of a uterine artery laceration. The didactic-only group did not receive any simulation training. After the lecture and simulation training, an evaluation was scheduled approximately six to eight weeks later (Figure *1*).

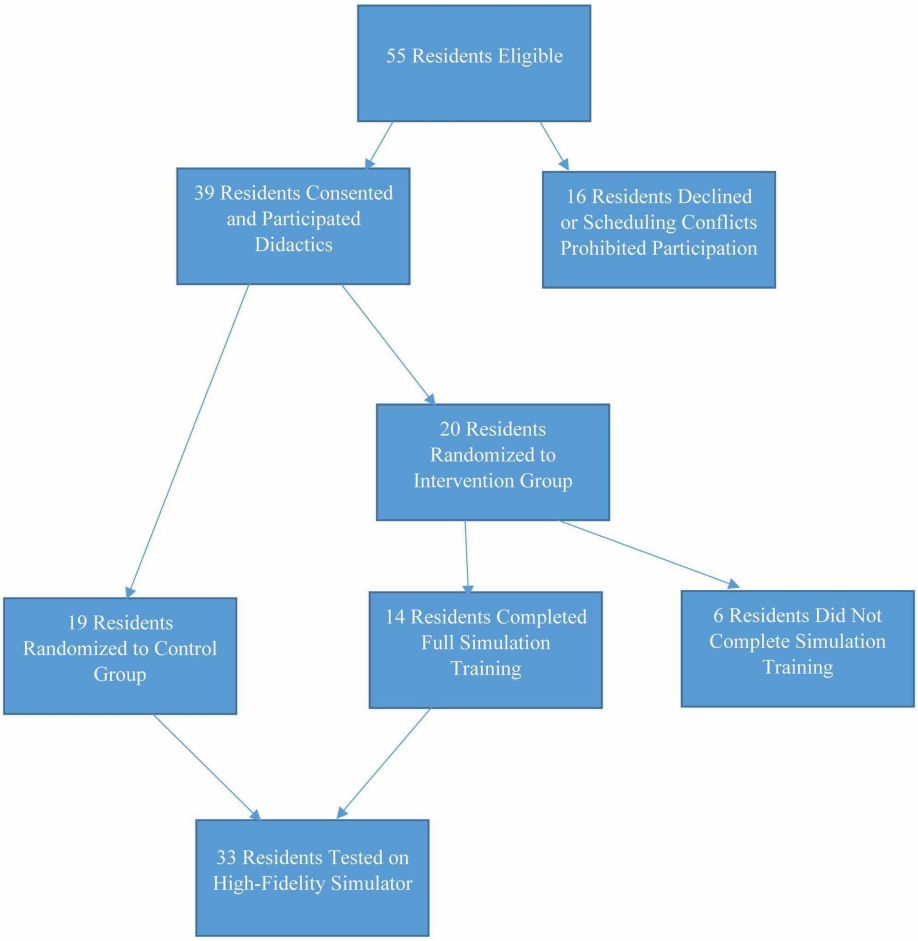

FIGURE 1: Flow Chart of Paricipant Inclusion

A high-fidelity trainer made by Operative Experience© was used for the skills evaluation (Figure *2*). Thirty-eight experienced obstetricians had previously assessed this simulator and 94.9% rated the simulator as both realistic and adequate for training on each step of a cesarean section (Figure *3*) [12].

Simulator Part	Cost
C-section skills training system (incision and repair base)	$8,525
Abdominal incision and repair inserts (AIR 2.0)	$36
Uterine incision inserts (UII)	$19
Fetal Extraction Trainer (FET 2.0)	$10,500
Postpartum Hemorrhage Control Trainer (PPH 2.0)	$9,650
PPH Replacement Uterus (1 extra included with each trainer)	$1,135
Emergency C-Section Trainer (OB C-Section 2.0)	$14,900
C-Section operable Inserts	$525

FIGURE 2: Simulator Cost Breakdown

	Not realistic at all, NOT adequate for training	Somewhat realistic, NOT adequate for training	Somewhat realistic, ADEQUATE for training	Realistic, ADEQUATE for training	Very realistic (almost like real life), ADEQUATE for training	Rating Count
Abdominal skin incision	0.0% (0)	3.1% (1)	12.5% (4)	**56.3% (18)**	28.1% (9)	32
Fascial incision	0.0% (0)	7.1% (2)	21.4% (6)	**42.9% (12)**	28.6% (8)	28
Peritoneum	0.0% (0)	8.7% (2)	21.7% (5)	**39.1% (9)**	30.4% (7)	23
Creation of bladder flap	0.0% (0)	16.7% (4)	16.7% (4)	**37.5% (9)**	29.2% (7)	24
Uterine incision	0.0% (0)	3.1% (1)	18.8% (6)	**46.9% (15)**	31.3% (10)	32
Uterine bleeding	0.0% (0)	0.0% (0)	17.2% (5)	**41.4% (12)**	**41.4% (12)**	29
Uterine lacerations	0.0% (0)	0.0% (0)	17.1% (6)	40.0% (14)	**42.9% (15)**	35
Delivery of fetus	0.0% (0)	3.2% (1)	12.9% (4)	35.5% (11)	**48.4% (15)**	31
Delivery of placenta	0.0% (0)	6.3% (2)	18.8% (6)	34.4% (11)	**40.6% (13)**	32
Intraabdominal anatomy	0.0% (0)	3.6% (1)	21.4% (6)	**39.3% (11)**	35.7% (10)	28
Repair of uterus	0.0% (0)	5.9% (2)	14.7% (5)	32.4% (11)	**47.1% (16)**	34
Repair of abdominal incision	0.0% (0)	3.4% (1)	13.8% (4)	**44.8% (13)**	37.9% (11)	29
					answered question	**38**

FIGURE 3: Initial Review of Simulator

All participants were oriented to the high-fidelity simulator prior to evaluation. Orientation included demonstrating how the simulator was assembled and discussing the simulator's features, such as ability to replicate hemorrhage. Participants were presented a standardized scenario of a primigravid woman with arrest of dilation. They were instructed to conduct pre-operative counseling and to describe pre-operative care. Each participant was assisted during the operation by a person acting as a scrub tech who provided

instruments as requested, but otherwise did not offer guidance about technique or interventions. A standard cesarean section instrument set was utilized, along with standard drapes. After delivery of the fetus, the scenario was complicated by a postpartum hemorrhage secondary to both uterine artery laceration and uterine atony. The hemorrhage scenario concluded if appropriate management occurred or after five minutes had elapsed. At this point, they were instructed to proceed with closing the uterine and abdominal incisions. When the procedure was complete, the participants were asked to verbalize postoperative orders.

Participants were scored using a standardized evaluation form created for each portion of the procedure (Figure *4*) [13]. Additional evaluations were adapted from previously published literature to assess technical surgical skills and teamwork/communication (Figures *5*, *6*) [12,13].

PREOPERATIVE MANAGEMENT					
COUNSELING	Not Done	Done but incomplete, not in timely manner, or poorly	Done Well		
Counsels patient on indication for procedure	0	1	2		
Discusses risk of infection	0	1	2		
Discusses risk of hemorrhage / transfusion	0	1	2		
Discusses risk of injury to maternal organs	0	1	2		
Discusses risk of injury to fetus	0	1	2		
				Total Possible	10
PREOPERATIVE PREP					
Performs time out (Patient ID / Allergies / Procedure)	0	1	2		
Checks fetal heart rate prior to removing monitors	0	1	2		
Ensures antibiotics are administered preoperatve (within 60 minutes of skin incision)	0	1	2		
Ensures DVT prophylaxis (SCD in place or Heparin administered)	0	1	2		
Ensures hip roll / left lateral displacement done preoperative	0	1	2		
Aware of placenta location and Patient's HCT value	0	1	2		
Ensures foley catheter in place	0	1	2		
				Total Possible	14
OPERATIVE MANAGEMENT					
PROCEDURE (PART 1)					
Ensures adequate anesthesia level	0	1	3		
Performs appropriate abdominal incision (transverse) at correct level	0	1	3		
Incision and sharp extension of fascial layer	0	1	3		
Separates rectus muscle in the midline	0	1	3		
Dissects fascia off rectus	0	1	3		
Enters the peritoneum in a sharp or blunt manner	0	1	3		
Hysterotomy is a safe distance from bladder	0	1	3		
Performs low transverse uterine incision	0	1	3		
Extends incision in correct manner	0	1	3		
Delivers fetus from the uterine in atraumatic manner	0	1	3		
Asks for correct dose of oxytocin to be administered	0	1	3		
Spontaneous / traction for delivery of the placenta	0	1	3		
Clears clots / debris from uterus	0	1	3		
				Total Possible	36
HEMORRHAGE MANAGEMENT	0	1	3		
Identification of uterine artery laceration	0	1	3		
Suture ligation of uterine artery to stop hemorrhage	0	1	3		
Identify ureter prior to the repair	0	1	3		
Locates and protects ureter during the repair	0	1	3		
Recognizes uterine atony for continued bleeding	0	1	3		
Diagnosis PPH- treat/transfuse	0	1	3		
Specify emergency release of blood	0	1	3		
Administers at least one medication (in addition to oxytocin) correctly	0	1	3		
Evaluates if uterine compression suture would be beneficial prior to placing suture	0	1	3		
Performs B-lynch suture	0	1	3		
				Total Possible	33
PROCEDURE (PART 2)					
Chooses correct suture (0-vicyrl CTX)	0	1	3		
Reapproximates edges of the uterus	0	1	3		
Performs a running, locked suture	0	1	3		
Assesses uterine incision for hemostasis after repair	0	1	3		
Evaluates and comments on fallopian tubes / ovaries	0	1	3		
Reapproximates the fascial layer in running manner	0	1	3		
Reapproximates subcutaneous fat layer if needed	0	1	3		
Closure of skin with suture	0	1	3		
Evacuates vagina of clots	0	1	3		
Evaluates uterine tone	0	1	3		
				Total Possible	30
POSTOPERATIVE CARE					
Appropriate post-op medications ordered	0	1	2		
Encourages early ambulation	0	1	2		
Order CBC for 24 hours post-op.	0	1	2		
				Total Possible	6
				Total Points Possible	129

FIGURE 4: Cesarean Section Evaluation Form

	1	2	3	4	5
Respect for tissue	Frequently used unnecessary force on tissue or caused damage by inappropriate use of instruments.		Careful handling of tissue, but occasionally caused inadvertent damage.		Consistently handled tissues appropriately with minimal damage.
Time and motion	Many unnecessary moves.		Efficient time/ motion, but some unnecessary moves.		Economy of movement and maximum efficiency.
Instrument handling	Repeatedly makes tentative or awkward moves with instruments.		Competent use of instruments although occasionally appeared stiff or awkward.		Fluid moves with instruments and no awkwardness.
Knowledge of instruments	Frequently asked for the wrong instrument or used an inappropriate instrument.		Knew the names of most instruments and used appropriate instrument for the task.		Obviously familiar with the instruments required and their names.
Use of assistants	Consistently placed assistants poorly or failed to use assistants.		Good use of assistants most of the time.		Strategically used assistant to the best advantage at all times.
Flow of operation and forward planning.	Frequently stopped operating or needed to discuss next move.		Demonstrated ability for forward planning with steady progression of operative procedure.		Obviously planned course of operation with effortless flow from one move to the other.
Knowledge of specific procedure.	Deficient knowledge. Needed specific instruction at most operative steps.		Knew all important aspects of the operation.		Demonstrated familiarity with all aspects of the operation.

FIGURE 5: Technical Skill Evaluation (35 POINTS)

Detailed global 5-point rating scale and pass/failure score for Objective Structured Assessment of Technical Skill* [12]

How well did the Primary Surgeon:						
	N/A	Unacceptable	Poor	Average	Good	Perfect
ORIENT NEW MEMBERS (SBAR) during the scenario as they arrived?	0	1	2	3	4	5
Call for ADDITIONAL ASSISTANCE in a timely manner	0	1	2	3	4	5
Utilize CLOSED-LOOP COMMUNICATION	0	1	2	3	4	5
Maintain SITUATIONAL AWARENESS during the procedure	0	1	2	3	4	5
PRIORITIZE Surgical Interventions	0	1	2	3	4	5

FIGURE 6: Teamwork / Communication Evaluation (25 Points)

Evaluators were oriented to the form and expectations of ‘done but not accurate’ versus ‘done and accurate’ by two senior investigators (LF and SD) and the same person at each facility conducted all evaluations. Participants were given a final pass/fail assessment for the entire simulation based on the entire score and

the evaluators' subjective assessment of whether or not the participant safely and effectively performed the task.

Means and standard deviations were calculated to compare the two groups using Student's t-test. Statistics were performed in Microsoft Excel (Microsoft Office 365). For the pass/fail assessment, proportions were compared using Fisher's exact test.

Results

Fifty-five eligible residents were approached for enrollment. Thirty-nine residents from three institutions consented to participate. Nineteen were randomized to the control group and 20 were randomized to the intervention group for skills training. Randomization occurred within the specialty sub-groups (OB/GYN, Family Medicine, and General Surgery). Six residents randomized to the skills task training did not attend, therefore, a total of 33 residents completed the study, 19 in the control group and 14 in the intervention group. The breakdown by specialty was 16 OB/GYN interns, 11 Family Medicine chief residents, and six General Surgery chief residents (Figure *1*).

The simulation trained group had significantly better performance for the cesarean section procedural steps (56.6 +/- 12.3 vs 42.7 +/- 14.7; p=0.007) as well as hemorrhage management (22.3 +/- 5.7 vs. 13.6 +/- 6.1; p=0.0002). They also had significantly higher overall scores for all aspects of the simulation (129.9 +/- 23.8) vs. 101.0 +/- 32.4; p=0.008) (Figure *7*). There were no differences in preoperative counseling and management, postoperative management, overall technical skills, or teamwork (Figure *7*) [12,13]. Overall, 47% of the control group passed the evaluation, while 79% of the simulation group passed, although these results did not reach statistical significance (p=0.06).

	Preoperative Counseling	Preoperative Prep	Cesearean Section Procedure	Hemorrhage Management	Postoperative Care	Technical Surgical Skills*	Teamwork & Communication**	Overall Score
(Maximum Score Possible)	10	14	66	33	6	35	25	189
Control Group (n=19)	6.6 (+/- 2.2)	6.3 (+/- 3.1)	42.7 (+/- 14.7)	13.6 (+/- 6.1)	3.4 (+/- 1.3)	18.1 (+/- 7.5)	10.0 (+/- 4.5)	101.0 (+/- 32.4)
Simulation Group (n=14)	7.1 (+/- 1.6)	7.4 (+/- 2.6)	56.6 (+/- 12.3)	22.3 (+/- 5.7)	4.2 (+/- 1.4)	20.7 (+/- 6.0)	11.3 (+/- 4.4)	129.9 (+/- 23.8)
P-value	0.47	0.31	0.007	0.0002	0.09	0.28	0.41	0.008

FIGURE 7: Participation Evaluation Results

Discussion

We found that augmenting a didactic experience with training on task simulators improved the ability to perform a cesarean delivery and manage a post-partum hemorrhage on a high-fidelity simulator. OB/GYN residents generally learn to perform cesarean sections through an apprenticeship model involving learning, reviewing, and observing the steps of the procedure, and then operating under close observation. General surgery residents do not routinely receive training in cesarean deliveries and Family Practice residents may have variable exposure depending on their residency program and interests. General Surgery and Family Practice physicians may need to perform or assist with a cesarean section in urgent cases, or if they practice in rural or low resource areas. The traditional educational construct is limited in several aspects including the unpredictability of disease occurrence and patient presentation, variations in patient anatomy, high-stress environments, and presumed increase in patient risk due to the inexperience of a novice surgeon.

Simulation allows the trainee to gain procedural experience while eliminating patient risk and decreasing cognitive stress on the learner. It facilitates the provision of safe care while still meeting the learning goals of the trainee. Simulated complications and emergencies provide the opportunity to perform multiple repetitions until comfort and proficiency are achieved. In our study, one of the most striking differences was the improved management of post-partum hemorrhage by those who underwent simulated task training.

A prior study demonstrated that incorporating a low-cost simulator plus didactics improved performance on the ability to define the steps of a cesarean section (91% versus 61.5%) and perform the procedure [5]. The results of our intervention are consistent with the finding that simulation results in an observed improvement in the performance of the cesarean section. We did not observe a difference in the ability to conduct counseling, describe pre- or post-operative management, or teamwork, which is expected as we did not include simulated counseling and team communication in our training.

Limitations of this evaluation include the inability to evaluate procedural skills on a live patient, and lack of self-assessment of comfort with the procedure. We were also unable to control for participant use of outside

educational resources or individual task practice, which may have affected performance during the testing. General surgery chief residents also have a wealth of surgical experience compared to OB/GYN interns or Family Medicine residents, and this could have influenced both their learning curve and the technical skills assessment. Due to the small sample size, we did not separately analyze data based on specialty.

The creation of a full cesarean section simulation-training program is relevant to both military and civilian providers. The majority of procedures performed for non-military female patients during humanitarian missions are for gynecologic or obstetric care. One study reported that 20% of deployed OB/GYNs performed at least one cesarean section while in a combat zone [10]. Any surgeon, OB/GYN, or Family Medicine physician who is deploying or going on a humanitarian mission may be asked to perform a cesarean delivery and manage any associated complications. There is also evidence that even obstetric residents may not feel competent in some basic tasks within their own field [9].

Conclusions

Incorporation of a simulation-based training model into pre-deployment or pre-humanitarian mission training may improve knowledge of the procedure, confidence in performing or assisting, and enhance skills related to hemorrhage management. Further, we found that a simulation-training plan could easily be incorporated into residency programs.

Future plans include permanently incorporating cesarean section simulation into residency training, creating standardized video instruction in addition to lectures, adding simulation training for patient counseling and team communication skills, and evaluating surgical skills on live patients.

Additional Information

Disclosures

Human subjects: Consent was obtained by all participants in this study. Uniformed Services University issued approval OBGY-85-9155. **Animal subjects:** All authors have confirmed that this study did not involve animal subjects or tissue. **Conflicts of interest:** In compliance with the ICMJE uniform disclosure form, all authors declare the following: **Payment/services info:** This project was supported by a grant awarded by JPC-1, WBS: R.0014945.1.1.2. . **Financial relationships:** All authors have declared that they have no financial relationships at present or within the previous three years with any organizations that might have an interest in the submitted work. **Other relationships:** All authors have declared that there are no other relationships or activities that could appear to have influenced the submitted work.

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