Virtual simulation training for postpartum hemorrhage in low-to-moderate-volume hospitals in the US

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BACKGROUND: Maternal mortality in the United States is rising and many deaths are preventable. Emergencies, such as postpartum hemorrhage, occur less frequently in non-teaching, rural, and urban low-birth volume hospitals. There is an urgent need for accessible, evidence-based, and sustainable inter-professional education that creates the opportunity for clinical teams to practice their response to rare, but potentially devastating events.

OBJECTIVE: To assess the feasibility of virtual simulation training for the management of postpartum hemorrhage in low-to-moderate-volume delivery hospitals.

STUDY DESIGN: The study occurred between December 2021 and March 2022 within 8 non-academic hospitals in the United States with low-to-moderate-delivery volumes, randomized to one of two models: direct simulation training and train-the-trainer. In the direct simulation training model, simulation faculty conducted a virtual simulation training program with participants. In the train-the-trainer model, simulation faculty conducted virtual lessons with new simulation instructors on how to prepare and conduct a simulation course. Following this training, the instructors led their own simulation training program at their respective hospitals. The direct simulation training participants and students trained by new instructors from the train-the-trainer program were evaluated with a multiple-choice questionnaire on postpartum hemorrhage knowledge and a confidence and attitude survey at 3 timepoints: prior to, immediately after, and at 3 months post-training. Paired t-tests were performed to assess for changes in knowledge and confidence within teaching models across time points. ANOVA was performed to test cross-sectionally for differences in knowledge and confidence between teaching models at each time point.

RESULTS: Direct simulation training participants (n=22) and students of the train-the-trainer instructors (n=18) included nurses, certified nurse midwives and attending physicians in obstetrics, family practice or anesthesiology. Mean pre-course knowledge and confidence scores were not statistically different between direct simulation participants and the students of the instructors from the train-the-trainer course (79% +/-13 versus 75%+/-14, respectively, P-value=.45). Within the direct simulation group, knowledge and confidence scores significantly improved from pre- to immediately post-training (knowledge score mean difference 9.81 [95% CI 3.23−16.40], P-value<.01; confidence score mean difference 13.64 [95% CI 6.79−20.48], P-value<.01), which were maintained 3-months post-training. Within the train-the-trainer group, knowledge and confidence scores immediate post-intervention were not significantly different compared with pre-course or 3-month post-course scores. Mean knowledge scores were significantly greater for the direct simulation group compared to the train-the-trainer group immediately post-training (89%+/-7 versus 74%+/-8, P-value<.01) and at 3-months (88%+/-7 versus 76%+/-12, P-value<.01). Comparisons between groups showed no difference in confidence and attitude scores at these timepoints. Both direct simulation participants and train-the-trainer instructors preferred virtual education, or a hybrid structure, over in-person education.

CONCLUSION: Virtual education for obstetric simulation training is feasible, acceptable, and effective. Utilizing a direct simulation model for postpartum hemorrhage management resulted in enhanced knowledge acquisition and retention compared to a train-the-trainer model.

Key words: education, emergency, innovation, low-volume, moderate-volume, multidisciplinary, non-academic, postpartum hemorrhage, rural, technology, train-the-trainer

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Why was the study conducted?

- Simulation education enables providers to practice skills necessary for the multidisciplinary management of emergencies.
- Emergencies, such as postpartum hemorrhage, occur less frequently in non-academic hospitals with low-to-moderate delivery volumes. However, these hospitals have limited time, resources, and staff for simulation education.
- Virtual education models can reduce barriers associated with simulation education; however, the feasibility of virtual simulation training in obstetrics is unknown.

What are the key findings?

- Direct virtual obstetric simulation on postpartum hemorrhage is feasible, which is defined as being acceptable among participants and effective in improving knowledge and confidence.
- Train-the-trainer models can be adapted to a virtual platform, but additional effectiveness studies are needed.

What does the study add to what is already known?

- Virtual education, which has been proven effective in other procedural-based specialties, may offer a new paradigm in obstetric simulation training.

Introduction

The United States has approximately 700 to 800 pregnancy-related deaths annually[1] and is one of the only developed countries with a rising maternal mortality rate.[2] Maternal morbidity and mortality, of which postpartum hemorrhage (PPH) is a leading cause,[3,4] disproportionally affects individuals who are Black[3,5–7] and those that live in rural areas[8–10] and/or give birth at low delivery volume hospitals.[5,10,11] Often, PPH is preventable, with provider and system issues comprising the majority of contributing factors.[3]

To address this trend, The Joint Commission published new elements of performance prioritizing prevention, early recognition, and timely treatment for hemorrhage and hypertensive disorders of pregnancy.[12] Annual multidisciplinary drills with team debriefs are required to identify system issues with hemorrhage and severe hypertension response.[12] Therefore, there is an urgent need to implement evidence-based, multidisciplinary education equitably and sustainably across hospital systems.[13]

Virtual simulation education allows for remote didactics and assessment, while emphasizing experiential learning and psychological safety, which are cornerstones of adult learning.[14–17] It has the potential to reduce barriers for resource-limited hospitals to access evidence-based simulation education.[18,19] However, the effectiveness of virtual simulation training in obstetrics has not been well studied.

Our primary objective was to determine the feasibility of virtual simulation training for the management of PPH by multidisciplinary teams. Feasibility is defined as acceptability by participants and limited efficacy testing.[20] We created and deployed virtual direct simulation training (DST) and train-the-trainer (TTT) models in US non-academic hospitals with low- to moderate-delivery volumes. Acceptability was measured by satisfaction scores and qualitative interviews, whereas efficacy was measured as changes in knowledge and confidence in managing PPH from pre-training to immediately post- and 3-months post training. Our secondary objective was to compare the two virtual simulation education models to evaluate which yielded superior results: teaching participants directly or providing training for trainers who can conduct simulation with their own staff. We hypothesized that both DST and TTT models would be feasible to conduct, acceptable to participants, and result in improved knowledge and confidence in managing PPH.

Materials and methods

Simulation training materials

In 2021, simulation training materials were created at Stanford University School of Medicine by the Global Outreach-Mobile Obstetric Medical Simulation (GO MOMS) multidisciplinary team, comprised of physicians (obstetricians, maternal-fetal medicine [MFM] physicians, an obstetric anesthesiologist, and a neonatologist), labor and delivery nurses, simulation training specialists, instructional designers, media specialists, and writers. Content creators drew from clinical experience at a large, academic hospital, evidence-based research, and the most up-to-date clinical guidelines from professional organizations.

Asynchronous didactic DST content included 6 modules: an introduction to simulation, principles of simulation education, team communication skills, how virtual simulation training works, background on PPH and learning objectives for a PPH simulation scenario, plus care bundles, toolkits and cognitive aids for managing PPH. Asynchronous didactic TTT content expanded on the DST content; it included 10 modules that taught new simulation instructors how to prepare and conduct a simulation course tailored for their own hospital (Appendix 1). Modules were organized around key topics, for example how to define learning objectives and the art of debriefing. In addition to module development, content creators filmed a PPH simulation scenario for the TTT course that included demonstrations of common technical skills used during a PPH, such as uterine balloon tamponade device and B-Lynch suture placement. Members of the team also recorded an audio interview describing the benefits and challenges of simulation training and debriefing. DST or the TTT asynchronous content was reviewed prior to live virtual training with the expert simulation faculty.

Study design

This was a randomized feasibility study investigating two virtual models: DST and TTT. In the DST model, expert simulation faculty conducted a virtual simulation training program with participants. In the TTT model, expert simulation faculty conducted virtual lessons with new simulation instructors on how to prepare and conduct a simulation course. Following this training, the instructors then led their own simulation training program at their respective hospitals. Hospitals for both interventions were recruited through the California Maternal Quality Care Collaborative, Mississippi Maternal Perinatal Quality Collaboration and Louisiana Perinatal Quality Collaborative from November 2020 to June 2021. Letters introducing the intervention, study, and time commitment were distributed to eligible sites; interested hospitals appointed a leader who recruited additional local participants. Needs assessments were completed to define hospital structure, simulation experience and available resources. Block randomization to either a DST or TTT course took into consideration the annual number of vaginal births that served as a surrogate for hospital type. The study protocol was submitted to the Stanford University Institutional Review Board and deemed exempt (#47802).

Intervention

Stanford University School of Medicine expert simulation faculty conducted the virtual DST and TTT from December 2021 to May 2022. In the DST course, participants reviewed the asynchronous DST content prior to the virtual simulation course with expert simulation faculty. The training consisted of two, 2-hour, live virtual simulation trainings and debriefings via Zoom (Zoom Video Communications, San Jose, California). In utilizing this innovative simulation modality, participants verbalized actions to their co-participants and the simulation faculty. As scenarios evolved, faculty responded to the actions voiced by participants with images, vital sign data, and videos displayed on PowerPoint (Microsoft PowerPoint, Microsoft Corporation, Redmond, Washington) slides. In the TTT course, participants reviewed 1-hour of asynchronous TTT content followed by a live 2-hour session with Stanford's expert simulation faculty via Zoom. The TTT course participants became instructors and conducted their own in-person PPH simulation course at their respective hospitals with their labor and delivery staff. These simulations were observed either in-person or on video by Stanford's expert simulation faculty who provided feedback to the new instructors. After the study, DST participants and TTT instructors were given the opportunity to participate in the intervention to which they were not randomized.

Metrics

Direct simulation training participants and students receiving simulation training from the new TTT instructors completed both a multiple-choice questionnaire on PPH and confidence and attitude survey at three distinct time points: pre-course, immediately post-course, and 3 months post-course. The multiple-choice questionnaire comprised 29 knowledge- and skill-based questions (Appendices 2 and 3), which drew on PPH management guidelines from the Society of Maternal-Fetal Medicine, American College of Obstetricians and Gynecologists, Alliance for Innovation on Maternal Health and the California Maternal Quality Care Collaborative. Content was validated by a practicing nurse, MFM physician, and obstetric anesthesiologist. The confidence and attitude survey included 31 questions with a 5-point Likert scale that assessed confidence in diagnosing and managing PPH, implementing team communication techniques and leading a team. Post-course satisfaction surveys were distributed to study participants for internal review and course improvement. Study data were collected and managed using REDCap electronic data capture tools. The Stanford REDCap platform (http://redcap.stanford.edu) is developed and operated by Stanford Medicine Research IT team. The REDCap platform services at Stanford are subsidized by, (1) Stanford School of Medicine Research Office, and (2) the National Center for Research Resources and the National Center for Advancing Translational Sciences, National Institutes of Health, through grant UL1 TR001085.

Three months after completion of either virtual simulation course, participants were invited to complete a 30−60-minute semi-structured interview with members of our team. The interviews were designed to explore what participants learned, how their confidence was impacted by taking part in simulation training, and any behavioral or hospital system changes that resulted from the interventions. Metrics were designed to address the modified Kirkpatrick's levels of training evaluation. Gift cards, continuing medical education credits or maintenance of certification were provided when applicable to those who completed surveys or participated in interviews.

Statistical analysis

Participants of the DST course and students of the new TTT instructors, who completed at least 1 multiple-choice questionnaire or confidence and attitude survey, at one time point, were included for analysis. Primary outcomes included PPH knowledge, defined as the percentage correct on the multiple-choice questionnaire, and confidence, defined as the sum (maximum 155) of responses provided on the confidence and attitude survey. To determine the effect of each intervention in isolation, paired t-tests were performed to assess the within-participant changes in scores between pre- and immediate post-course, and between immediate post- and 3-months post-course. Mean differences and 95% confidence intervals are presented stratified by DST participants and students of the TTT instructors separately for knowledge and confidence scores. Participants were included if they completed the survey of interest at the two timepoints being compared.

To compare results of the DST participants with students of the TTT instructors, an analysis of variance was performed for knowledge and confidence scores pre-, immediate post-, and 3-months post-course. Means and standard deviations for each survey and timepoint are presented along with the *P*-value testing for significant differences between the learning modalities. All participants who completed the survey of interest at the specific timepoint were included.

Results

Eight hospitals were randomized to the DST or TTT model (Figure 1, Table 1). All hospitals were defined as urban, suburban or rural non-academic hospitals with low-to moderate-delivery volumes.[21] After randomization, two hospitals were unable to participate due to the COVID-19 pandemic and were replaced. As a result, hospitals that received the TTT model had higher annual vaginal deliveries and more dedicated surgical space compared to hospitals receiving the DST model (Table 1). There were 34 DST participants and 32 students of the TTT instructors. After excluding those who did not complete any surveys, the final analytic cohort included 22 DST participants and 18 students of the TTT

FIGURE 1
Flow diagram of study design. MCQ = multiple-choice questionnaire; PPH = postpartum hemorrhage.

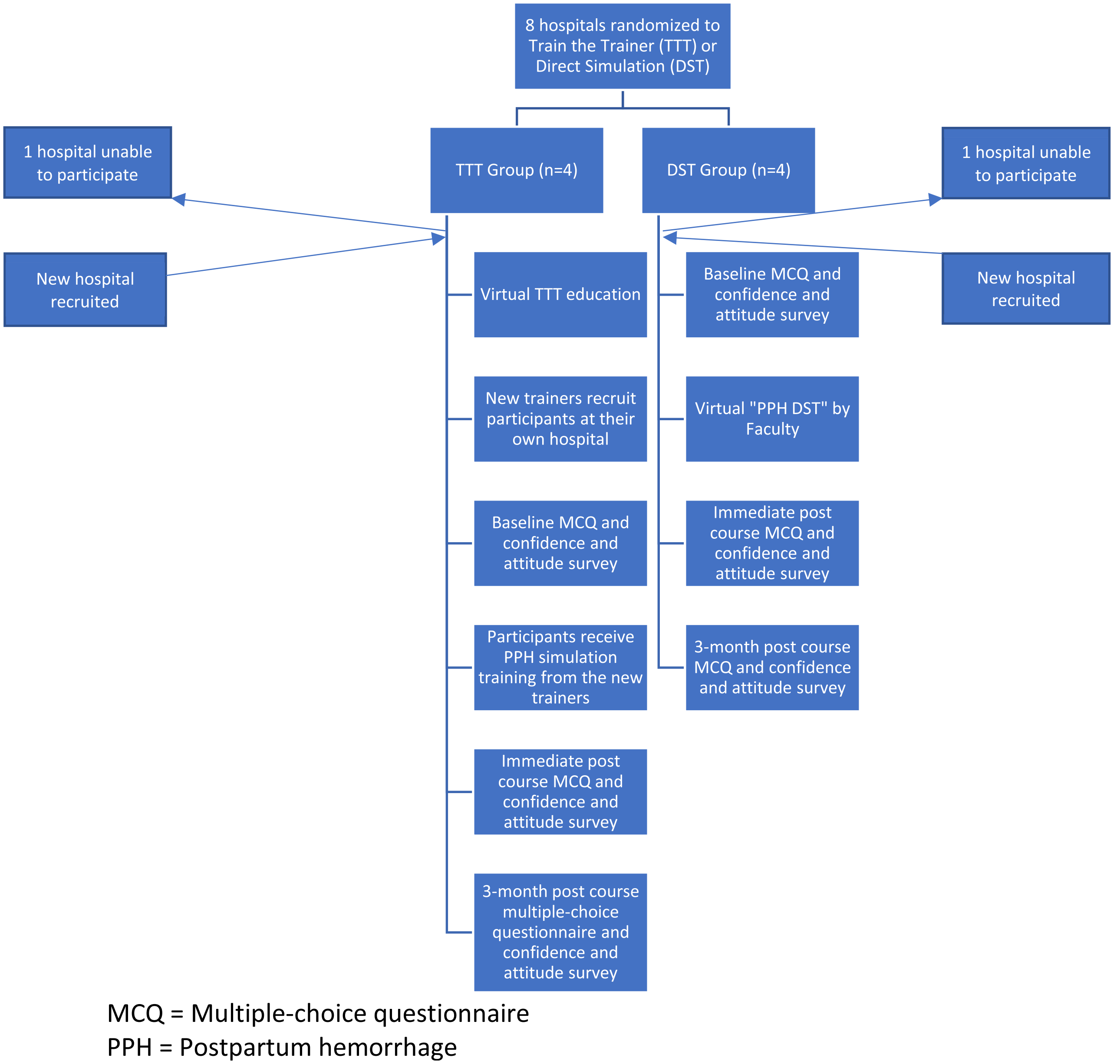

TABLE 1
Hospital demographics for 8 centers that were randomized to receive the direct simulation training or train the trainer courses from 2021−2022

	Direct simulation training		Train the trainer	
	Number	%	Number	%
State				
California	3	75	2	50
Louisiana	1	25	0	0
Mississippi	0	0	2	50
Hospital type				
District	1	25	0	0
County	1	25	2	50
Community	2	50	2	50
Setting				
Rural	3	75	2	50
Suburban	1	25	1	25
Urban	0	0	1	25
Vaginal deliveries per year (mean)	458	78[c]	1279	68[c]
Primary cesarean deliveries per year[a] (mean)	67		232	
All cesarean deliveries per year[b] (mean)	129	22[c]	591	32[c]
Number of dedicated obstetric operating rooms (mean)	1		2	
Number of sites with the following resources:				
Operating rooms on the obstetric unit	3	75	3	75
Number of labor and delivery rooms				
4−5	2	50	1	25
>5	2	50	3	75
Pediatrics in house 24/7	1	25	1	25
Gynecology oncology on call from home	3	75	2	50
Interventional radiology in-house or on call from home	1	25	1	25
Blood bank on site	3	75	4	100
Postpartum hemorrhage cart	4	100	4	100
Massive transfusion protocol	3	75	4	100
Rapid infuser device	1	25	3	75

[a] Two-missing value; [b] One-missing value; [c] Percentage calculated based on average vaginal deliveries and all cesarean deliveries per year.

instructors (Appendix 4). The participants differed in their age, experience, and specialty (Table 2). The DST group was older, with wider professional experience and was comprised of more attending physicians from diverse specialties. However, the DST group, on average, managed fewer deliveries, fewer hemorrhages, and had less simulation experience.

DST intervention

Of the 22 DST participants, 13 sequentially completed the pre- and immediate post-course PPH questionnaire, while 9 did for the immediate post- and 3-month post-course. For DST participants, 65% completed at least 1 survey. Within the DST group, PPH knowledge scores significantly improved from pre-course to the immediate post-course assessment (mean difference 9.81, 95% CI 3.23−16.40, *P*-value<.01) (Table 3). The mean difference in PPH knowledge scores did not significantly change between the immediate and the 3-month post-course assessments (mean difference -2.30, 95% CI -8.23 to 3.63, *P*-value=.40). Confidence and attitude scores improved immediately post-course compared to pre-course assessment (mean difference 13.64, 95% CI 6.79−20.48, *P*-value<.01), and there was no significant difference between immediate post-course and 3-month post-course assessments (mean difference 6.50, 95% CI -9.45 to 22.45, *P*-value=.37). Across all metrics, gains were greatest among confidence and attitude scores immediately post-course compared to baseline.

TTT intervention

Of the 18 students of the TTT instructors, 6 sequentially completed the pre- and immediate post-course PPH questionnaire, 7 did for the immediate post- and 3-month post-course timepoints. For students of the TTT instructors, 56% completed at least 1 survey. PPH knowledge scores remained relatively unchanged despite the intervention. There was no statistically significant difference between the pre- and immediate post-course scores (mean difference 4.60, 95% CI -10.7 to 19.89, *P*=.47), nor the immediate post- and 3-month post-course scores (mean difference -0.49, 95% CI -10.5 to 9.50, *P*=.91). Similarly, confidence and attitude scores were not statistically different at any timepoints (Table 3).

Comparison between interventions

Pre-course PPH knowledge scores did not significantly differ between DST participants and students of the TTT instructors (79% versus 75% respectively, *P*-value=.45) (Table 4). Mean immediate post-course scores were significantly higher among DST participants compared with students of the

TABLE 2
Individual participant demographics, characteristics and work experience who participated in the direct simulation training or were students of the instructors who received the train the trainer course from 2021–2022

	Direct simulation training		Train the trainer	
	N	%	*N*	%
Total	22		18	
Affiliated hospital				
Site 1	8	36.36		
Site 2	4	18.18		
Site 3	6	27.27		
Site 4	4	18.18		
Site 5			3	16.67
Site 6			7	38.89
Site 7			6	33.33
Site 8			2	11.11
Age				
<30 years	2	9.09	3	23.08
30–39 years	6	27.27	3	23.08
40–49 years	7	31.82	3	23.08
50–59 years	5	22.73	3	23.08
60–69 years	2	9.09	1	7.69
Missing			5	
Level of training				
Registered nurse	8	36.36	5	38.46
Bachelor of nursing	5	22.73	3	23.08
Certified nurse midwife	3	13.64	2	15.38
Attending physician	5	22.73	2	15.38
Other	1	4.55	1	7.69
Missing			5	
Specialty				
Obstetrics	20	90.91	13	100
Family practice	1	4.55		
Anesthesiology	1	4.55		
Missing			5	
Years of professional experience in this profession				
0–4	3	14.29	3	25
5–10	6	28.57	3	25
11–20	5	23.81	2	16.67
≥21	7	33.33	4	33.33
Missing			5	
How many years have you been working in this hospital?				
0–4	11	50	7	58.33
5–10	4	18.18	3	25
11–20	3	13.64	2	16.67
≥21	4	18.18		
Missing			5	

(continued)

TTT instructors (89% versus 74% respectively, *P*-value<.01). Similarly, at 3-months post-course, the mean knowledge score for the DST group was significantly greater than that of the TTT group by 12 percentage points (88% versus 76% respectively, *P*-value<.01). Confidence and attitude scores were not statistically different between DST and TTT groups at any of the 3 timepoints assessed.

Satisfaction

Both DST and TTT groups indicated a virtual or hybrid (virtual and in-person components) course was preferred compared with an in-person option. Main reasons for this included flexibility and convenience (Table 5). For students of the TTT instructors, the majority would have preferred instructors from outside their institution who could bring diverse perspectives. Students shared that having outside faculty lead the simulation course would alleviate pressure to perform in front of peers or leadership.

Interviews

Four interviews were conducted, three of which were with labor and delivery nurses, and one was with a fellowship-trained anesthesiologist. Two of the interviewees participated in both DST and TTT courses; one participated in only DST, and another in only TTT. Interviewees found the virtual simulation training content was easy to navigate, focused, and directly applicable to patient care at their respective hospitals. While some of the sense of urgency that characterizes obstetric events could not be replicated in the virtual format, interviewees still reported improvements in communication and teamwork after completing the intervention. The most valuable takeaways from the intervention included learning standardized communication techniques (e.g., recaps), strengthening interdisciplinary teamwork (e.g., reviewing workflows and adapting/implementing algorithms), and discovering how to better lead debriefs. Main barriers to success included ongoing staffing issues, inability to schedule a reliable simulation space with fluctuating census, and

TABLE 2
Individual participant demographics, characteristics and work experience who participated in the direct simulation training or were students of the instructors who received the train the trainer course from 2021–2022
(continued)

	Direct simulation training		Train the trainer	
	N	%	*N*	%
Which shift do you normally work?				
Day	13	59.09	8	61.54
Overnight	3	13.64	1	7.69
Mixed	6	27.27	4	30.77
Missing			5	
Approximately how many vaginal deliveries do you perform/or are you involved in during a typical month?				
0–5	10	47.62	3	25
6–10	8	38.1	4	33.33
11–15	2	9.52	5	41.67
16–20	1	4.76		
Missing	1		6	
Approximately how many hemorrhages (>1000 cc/delivery) do you manage or are you involved in during a typical month?				
0	4	20	3	25
1	13	65	5	41.67
2	2	10	3	25
≥3	1	5	1	8.33
Missing	2		6	
Have you participated in simulations in the past?				
No	8	36.36	1	7.69
Yes	14	63.64	12	92.31
Missing			5	
What was your role in simulation?				
Teacher of simulation	5	35.71	3	25
Participant in simulation	9	64.29	9	75
Not applicable	8		1	
Missing			5	
How often have you participated in simulation?				
One-time event	2	14.29	1	8.33
More than a one-time event	12	85.71	11	91.67
Not applicable	8		1	
Missing			5	

IV = intravenous.

cultural resistance to simulation training participation. One interviewee highlighted the importance of adapting the simulation course and materials to reflect challenges facing rural hospitals, such as modifying protocols to account for limited personnel and resources.

Discussion/comment

Principal findings

Our study illustrates that both DST and TTT are feasible models of virtual obstetric simulation training, as demonstrated by the participant acceptance and efficacy in the DST arm. Compared to pre-course assessments, DST participants improved their PPH knowledge and confidence scores immediately post course, which was retained at 3-months post course. In contrast, knowledge, and confidence scores for students of the TTT instructors remained relatively unchanged. Directly comparing the virtual simulation training models indicates DST may be more effective than TTT for knowledge acquisition and retention. Further efficacy testing of virtual simulation education models is needed in large, randomized studies.

Results in context of what is known

Simulation training improves knowledge,[22–31] management skills[32–40] and team performance[23,27,30,36,38,41–43] in obstetric emergencies. There is emerging evidence that it addresses Kirkpatrick's 4th level of training evaluation through improving patient outcomes[39,44–54] and quality of care, as demonstrated through reduction in malpractice claims[55] and premiums[56] following simulation training. Many well-developed obstetric simulation programs exist;[57] however, innovation is needed to address scalability and sustainability while retaining fidelity.[13,32,58,59]

Virtual simulation education has been implemented[60–62] and evaluated in other procedural and emergency-based specialties that demand application of time-sensitive, complex algorithms, such as neurosurgery,[63] anesthesiology,[64,65] otolaryngology,[66] gynecology,[67] dentistry,[68] and pediatrics.[69] It is an effective and acceptable alternative to in-person simulation[66] that results in the transference of knowledge,[64,69] confidence,[69] and skills.[65] During the COVID-19 pandemic, a mixed methods study of learners, facilitators, and simulation specialists demonstrated that virtual simulation increased vignette-style learning, reduced performance-based anxiety, and facilitated discussion.[61]

Within obstetrics, the COVID-19 pandemic provided the impetus for virtual simulation platforms.[70–73] A crossover randomized controlled trial of midwifery students compared PPH virtual simulation using a 3D-automated

TABLE 3

Mean difference in knowledge, confidence, and attitude scores for participants of virtual direct simulation training and students of the instructors who received the train the trainer course for pre-, immediately post-, and at 3-months post-training

		Immediate post-course			3-month post-course		
		Completed pre- and immediate post-course questionnaires			Completed immediate post- and 3-months post-course questionnaires		
Course	Metric	*N*	Mean difference (95% CI)[a]	*P*-value[b]	*N*	Mean difference (95% CI)[a]	*P*-value[b]
Direct simulation training	**Postpartum hemorrhage knowledge score**[c]	13	9.81 (3.23 to 16.40)	<.01	9	-2.30 (-8.23 to 3.63)	.40
	Confidence and attitude score[d]	11	13.64 (6.79 to 20.48)	<.01	8	6.50 (-9.45 to 22.45)	.37
Train the trainer	**Postpartum hemorrhage knowledge score**[c]	6	4.60 (-10.7 to 19.89)	.47	7	-0.49 (-10.5 to 9.50)	.91
	Confidence and attitude score[d]	5	22.20 (-8.53 to 52.93)	.12	9	-6.78 (-19.3 to 5.77)	.25

N = number of participants.

[a] Mean difference for participants that completed both timepoints; [b] Paired t-test; [c] Percentage correct out of 29 multiple-choice questions (range 0%—100%) based on published guidelines from the Society of Maternal Fetal Medicine, the American College of Obstetrics and Gynecology, the Alliance for Innovation on Maternal Health and the California Maternal Quality Care Collaborative; [d] Sum of a 31-question confidence and attitude survey rated on a 5-point Likert scale (range 0—155).

environment with traditional supervised classroom work. Satisfaction was significantly higher among students who received virtual education, while their knowledge scores were comparable to those performing in-person work.[74]

Clinical implications

To the best of our knowledge, our study is the first to quantitatively assess live virtual simulation in obstetrics. Our data corroborates that of other specialties—that virtual simulation is feasible and efficacious; it adds that it can enhance communication and teamwork. A strength of our study was the development of two virtual simulation models. Our work also augments existing literature, expanding our understanding of what successful TTT models may require.

Obstetric education using TTT models has been studied in multiple resource settings,[54,75—82] but few studies employed a virtual component.[77] The TTT model promotes participatory learning and fosters self-confidence in instructors to implement in-situ simulation in their own environment.[80] Training instructors who have the clinical acumen and contextual awareness to tailor scenarios to their institution may maximize system improvements and learning.[76] However, balances must be

TABLE 4

Knowledge, confidence and attitude scores for pre-, immediately post- and 3-months after postpartum hemorrhage training compared between direct simulation training and students of train the trainer instructors

	Pre-course					Immediate post-course					3-month post-course				
	DST		TTT			DST		TTT			DST		TTT		
Course	*N*	Mean ±std	*N*	Mean ±std	*P*-value[a]	*N*	Mean ±std	*N*	Mean ±std	*P*-value[a]	*N*	Mean ±std	*N*	Mean ±std	*P*-value[a]
Postpartum hemorrhage knowledge score, % correct[b]	22	79 ±13	12	75 ±14	.45	13	89 ±7	9	74 ±8	<.01	13	88 ±7	10	76 ±12	<.01
Confidence and attitude survey, sum[c]	19	120 ±17	10	125 ±16	.51	12	138 ±14	10	143 ±9	.35	10	142 ±9	11	138 ±17	.59

DST = direct simulation training; TTT = train the trainer; STD = standard deviation; N = number of participants.

[a] Comparison between students of train the trainer instructors and participants of direct simulation training across three timepoints using analysis of variance; [b] Percentage correct out of 29 multiple-choice questions (range 0-100%) based on published guidelines from the Society of Maternal Fetal Medicine, the American College of Obstetrics and Gynecology, the Alliance for Innovation on Maternal Health and the California Maternal Quality Care Collaborative; [c] Sum of a 31-question confidence and attitude survey rated on a 5-point Likert scale (range 0—155).

TABLE 5
Results of post-course satisfaction survey for the direct simulation training, train the trainers and students of the train the trainer instructors

Question/answer	Direct simulation training		Train the trainer		Students of train the trainer instructors	
	N	%	*N*	%	*N*	%
Total completed surveys	17		25		14	
What method of teaching do you prefer?						
Virtual	5	29	12	48	NA	NA
In-person	3	18	3	12	NA	NA
Hybrid	9	53	10	40	NA	NA
Would you prefer this course is taught by instructors from your own institution or outside?						
Outside institution	NA	NA	NA	NA	3	71
My own institution	NA	NA	NA	NA	10	21

NA: not applicable.

Hybrid: virtual and in person.

in place to ensure fidelity of the content transferred to trainers[54,78] and sustainability.[76] Training instructors virtually was feasible, but our results indicate students who received simulation training from recipients of the TTT course did not significantly improve their knowledge or confidence. This is not to say that a TTT pedagogy is not efficacious, but rather the way in which our course was designed may have impacted knowledge transfer. Participants expressed a preference for outside faculty to gain exposure to diverse perspectives and maintain anonymity in a learning environment. External faculty may engage more effectively with participants, overcoming educational and hierarchical barriers, which could translate to improved knowledge transfer. We hypothesize TTT participants naïve to simulation would benefit from taking the DST course prior to becoming an instructor[75] to standardize knowledge. Additionally, capacity building for new instructors requires ongoing mentorship, some of which may happen in-person to facilitate skill transfer.[76,78]

Research implications

Our intent was to demonstrate acceptability and effectiveness of virtual obstetric simulation education. Future studies should rigorously evaluate the intervention through applying skill-based assessment[83] (Kirkpatrick's 2nd level), behavior change (Kirkpatrick's 3rd level), and patient outcomes (Kirkpatrick's 4th level).[32] Educational models should be tested among other hospital types and cultures to address generalizability. Local providers should be recruited and involved in future course development to ensure the course is tailored to the unique challenges of delivering care in their hospital.

Strengths and limitations

Our study is not without limitations. Despite incentivization, survey response rate remained modest (Appendices 4 and 5). Those who completed surveys were an engaged, self-selecting cohort, introducing sampling bias. Particularly for the qualitative interviews, participation was limited and lacked students of the TTT instructors. Therefore, we do not have the same depth of knowledge as their experience. Additionally, this was a feasibility study, thus, it was not powered to detect differences among the TTT group or account for differences across study sites or between participants. Baseline demographics differed between DST participants and students of the TTT instructors. Most notably, DST participants were more likely to be physicians, were older, and had more experience in their profession and at their institution yet had less simulation experience. It is unclear whether or how the demographic differences between groups impacted knowledge and confidence scores or growth potential. Additionally, while we compared scores from the DST participants and students of the TTT instructors, instructors were encouraged to adapt content to their institution. Lastly, our study had follow-up at 3-months, but most data indicate extinguishment of knowledge near 1-year following intervention. Therefore, we cannot comment on the cadence required for repeat courses.

Conclusions

We present evidence supporting virtual, live simulation education as a viable option for hospitals of low-to-moderate-delivery volumes in the US. Virtual simulation training leverages resources concentrated at academic centers to support non-academic hospitals that may have limited time, resources, and simulation staff. It can build the capacity of low-to-moderate-delivery volume hospitals to meet regulatory requirements, while enhancing management of obstetric emergencies.[9] With a TTT model, teaching how to perform simulation does not guarantee fidelity in outcomes[34,59] and long-term mentorship is likely required.

Glossary

TTT: train the trainer
DST: Direct simulation training

Declaration of competing interest

The authors have no conflicts of interest.

CRediT authorship contribution statement

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Supplementary materials

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