Reducing trainee mistakes. Better performance with changing to a high-fidelity simulation system?

Aino Ritva Weyers; Gabriel von Waldenfels, MD; Pimrapat Gebert, PhD; Wolfgang Henrich, MD, PhD; Larry Hinkson, MBBS, MD, MRCOG, FRCOG

BACKGROUND: Postpartum hemorrhage is a significant cause of both maternal morbidity and mortality worldwide and is increasing in incidence. This study aimed to assess improvement and identify shortcomings in trainee performance in different simulation systems in the management of postpartum hemorrhage.

OBJECTIVE: To perform a pilot study evaluating and comparing high- and low-fidelity simulation models, assessing improvement in repeated performance with high-fidelity mode and identifying mistakes made assessed using Objective Structured Assessment of Technical Skills and thereby exploring what aspects of emergency management of postpartum hemorrhage should be prioritized in teaching settings and assessing what simulation setup is most effective in achieving competence.

STUDY DESIGN: This was a prospective randomized, single-blinded, single-institution trial in a population of 17 junior obstetrical trainees at the Charité University Hospital Obstetric Simulation Center in Berlin. Trainees were randomized into 2 groups, with either initial low-fidelity simulation or high-fidelity simulation, followed by repeated assessment of performance, using the high-fidelity model simulation system. Individual simulation sessions were video-recorded and transcribed, and the timing of interventions was documented. Standardized Objective Structured Assessment of Technical Skills forms were used as a checklist for performance.

RESULTS: There was a statistically significant general improvement in performance (P=.02; 24.7−27.2 of 31.0 points; average of 8.7%) in the second cycle of simulation assessment and a statistically significant training effect (P=.043; 24.4−28.4 of 31.0 points; average of 12.9%) in the group that underwent repeat simulation assessment from the initial low-fidelity system to the high-fidelity system compared with the group using the same high-fidelity setup (P=.276; 25.0−25.8 of 31.0; average of 2.4%).

CONCLUSION: There was an improvement in the performance when trainees underwent a repeated cycle of simulation assessment changing from a low-fidelity system to a high-fidelity system. Simulation assessment can identify mistakes and learning gaps that are important for obstetrical trainees. This study found that trainees make the same mistakes, regardless of which simulation model was initially used.

Key words: effective learning, emergency drill, learning format, Objective Structured Assessment of Technical Skills, postpartum hemorrhage, proficiency, quality of care, simulation assessment script, simulation-based learning

From the Department of Obstetrics, Charité University Hospital, Berlin, Germany (Ms Weyers and Drs von Waldenfels, Henrich, and Hinkson); Department of Obstetrics and Gynecology, University of Bonn, Bonn, Germany (Ms Weyers); Institute of Biometry and Clinical Epidemiology, Charité – Universitätsmedizin Berlin, corporate member of Freie Universität Berlin, Humboldt-Universität zu Berlin, and Berlin Institute of Health, Berlin, Germany (Dr Gebert); Berlin Institute of Health, Berlin, Germany (Dr Gebert).

Ethical approval was granted by the Ethics Commission of the Charité University Hospital.

This study was self-funded.

The authors report no conflict of interest.

Informed consent was obtained of all trainees. No personal information or detail is included.

The work described has not been published previously.

Data sharing is available on reasonable request from the corresponding author. Datasets will be shared. Individual participant data will not be shared.

Cite this article as: Weyers AR, von Waldenfels G, Gebert P, et al. Reducing trainee mistakes. Better performance with changing to a high-fidelity simulation system? Am J Obstet Gynecol Glob Rep 2024;XX:x.ex−x.ex.

Corresponding authors: Aino Ritva Weyers; Larry Hinkson, MBBS, MD, MRCOG, FRCOG. aino-ritva.weyers@charite.de, Larry.Hinkson@charite.de

2666-5778/$36.00

http://dx.doi.org/10.1016/j.xagr.2024.100326

AJOG Global Reports at a Glance

Why was this study conducted?

This study aimed to foster knowledge regarding which aspects of the management of postpartum hemorrhage (PPH) should be prioritized in training when aiming for the reduction of repeated shortcomings.

Key findings

The key findings of the study were that there was a general improvement through simulation assessment and a significant training effect when changing from a low-fidelity setup to a high-fidelity setup.

What does this add to what is known?

The study adds essential knowledge focusing on common shortcomings in the management of PPH that should be more emphasized and incorporated into training protocols: application of fibrinogen; emptying the bladder; considering compression suture, uterine artery ligature, and hysterectomy; performing vaginal examination looking for trauma; estimating the blood loss; establishing intravenous lines; giving blood products; considering the application of sulprostone or carbetocin while stopping oxytocin and continuing manual compression of the uterus; and planning a team debriefing.

Introduction

Postpartum hemorrhage (PPH) is a significant cause of both maternal morbidity and mortality worldwide and has increased in incidence (between 1% and 3% of all deliveries) in the last decades.[1−9] Studies have shown that major substandard care is a contributing factor.

We identified the importance of educating trainees on existing management strategies to reduce this rise in PPH.[10−14] Simulation-based training has been widely recommended as one of these strategies and has shown to be beneficial not only in obstetrics generally but also for PPH in particular.[10,15−21] Gavin et al[22] reported on the widespread acceptance of simulation-based training in which the American College of Obstetricians and Gynecologists conducts simulation courses on obstetrical emergencies. The American Board of Obstetrics and Gynecology recognizes it as an innovative approach to assess skills and practice, and the Accreditation Council for Graduate Medical Education identifies it as an effective means of educating trainees. Of note, one advantage of simulation training is that trainees take an active role in decision-making and are exposed to the possibility of making mistakes. Learning through this process is higher than passive theoretical learning where potential decision-making mistakes cannot be identified. Although many agree on the importance of establishing simulation training sessions and planning their implementation, consideration should be given to optimizing such training with emphasis on aiming for a high trainee performance. As there are various possible simulation training setups, varying from traditional, low-budget, low-fidelity setups to complex, high-fidelity setups with artificial intelligence (AI) and computer assistance, those tasked with the education of trainees and medical professionals have the responsibility of setting up such systems through evaluation of the benefits, costs, advantages, and disadvantages. Our objective was to perform a pilot study evaluating and comparing high- and low-fidelity simulation models, assessing improvement in repeated performance with high-fidelity mode, and identifying mistakes made assessed using Objective Structured Assessment of Technical Skills (OSATS) and through that exploring what aspects of emergency management of PPH should be prioritized in teaching settings as well as what simulation setup is most effective in achieving competence.

Materials and Methods

A randomized, single-blinded, single-institution trial was conducted between July 2020 and July 2021 at the Department of Obstetrics, Charité University Hospital, Berlin, Germany, in a population of medical residents of gynecology and obstetrics. Their performance during the simulation was assessed using standardized OSATS as a checklist rated on a dichotomous scale to identify frequent mistakes (score 1 = requirements met, action taken correctly; score 0 = requirements not met, action not taken or not taken correctly). OSATS is widely used as a reproducible tool for measuring technical skills in surgical and nonsurgical training settings. Significant research supports the validity of OSATS for simulation-based assessments.[23−26] Approval for this study was obtained from the personnel board and ethics board of the Charité University Hospital. Study participants consisted of 17 trainees, all working within the first 2 and a half years of their obstetrical career (out of 28 residents) in the obstetrical team at the Charité University within the period of the study. All trainees meeting the mentioned criteria were asked to participate. Other than informed consent and no language barrier, there was no specific inclusion or exclusion criterion. Exclusion occurred because of logistical difficulties, such as having completed the 2-year rotation.

Procedure

In general, the setup in our simulation center was standardized for each simulation regarding the supply of material and set up ahead of simulation commencement and depending on the allocated group (high or low fidelity). We played an audio recording giving each participant the same information that specified the woman's age, gravidity, parity, and gestational age and detailed the chief complaint before starting a simulation to avoid intrateacher variabilities. Keeping the script consisting of postpartum bleeding after a vaginal delivery because of retained placental tissue without labor characteristics influencing the management, with >500 mL of fake blood on the bedsheets and a plastic placenta model with a macroscopically missing part, and emergency-specific material, and the sequence the same, we designed 2 different setups. The first setup was defined as low fidelity, and the second setup was defined as high fidelity. To compare low- and high-fidelity simulations, we randomized the cohort of medical professionals into group 1 and group 2. Group assignment was performed by 1 of 2 instructors using a computer-generated randomization list with a 1:1 allocation ratio without blocking.

High-fidelity simulation consisted of using a birth simulator attempting to reproduce reality in greater detail, providing visible, audible, and tactile cues. We used a mannequin with anatomic accuracy (SimMom; Laerdal Medical: Wappingers Falls, New York, USA and Limbs & Things: Savannah, Georgia, USA) representing a full-term pregnant adult woman lying on a bed that could respond to clinical intervention, instructor control, and preprogrammed scenario, such as programmed bleeding, and allowed for the observation of both maternal and fetal vital signs. The vital parameters controlled by 1 of 2 instructors could be seen by the participants when they decided to measure the blood pressure or heart frequency of the mother and fetus. An algorithm for the scenarios was created with a specialized software and saved in the computer to have the simulator act independently and standardized following the treatment (or lack of treatment) administered by the participants.

Our low-fidelity simulation, providing a narrow portion of reality, consisted of an adult torso model (Little Anne; Laerdal Medical, Stavanger, Norway) and a baby mannequin. Moreover, it differed from the high-fidelity setup in that there was no provision of dynamic digital monitoring of the vital signs but only verbally announced vital parameters when participants decided to take vital signs. This required more interaction, guidance, and narration from the facilitator of the scenario compared with the high-fidelity simulation.

To assess the training effect, we retested some of our participants. When retesting, independent of the setup of the first simulation, every participant underwent a high-fidelity simulation. No feedback was given until the second simulation round was completed. This was performed purposefully to keep the second round of assessments balanced and avoid bias between the groups. The simulations were filmed for further evaluation.

Assessment

We designed the OSATS (see Figure 2) with a defined task-specific checklist on a dichotomous scale (judgment: 1 = requirements met, action taken correctly; 0 = requirements not met, action not taken or not taken correctly) of the emergency according to the highest standard of best-case care based on recommendations in international guidelines.[15,16]

Each item was approved by a leading specialist in obstetrics. This is in line with other studies conducted defining OSATS as checklists with items typically reflecting key task elements.[23,24]

The OSATS was based on 3 levels of evaluation: first, immediate assessment in real time during the simulation, including taking notes by one member of the research team, second, during the debriefing of the conducting research team after the simulation focusing mainly on the technical aspects, such as maneuvers, and third and more importantly, detailed assessment conducted during the transcription of the whole performance by reviewing the video material. Accordingly, communication and decision times were allocated to specific tasks while also categorizing communication with the midwife and team and communication with the pregnant person to create maximal transparency, traceability, and reproducibility regarding the assessment. Video analysis is a method used in a wide spectrum of fields, including medicine imaging processes in radiology departments, training of psychotherapists or general practitioners, and therapy evaluation of children's behavior in stressful situations and sports.[25–27]

To grade each participant's performance, we calculated an individual total score by summing up the points given for each of the items on the task-specific checklist, with 1 point for correctly performing each item and 0 points for not performing or not correctly performing. Thus, a higher score indicates greater proficiency.

Furthermore, in the sense of qualitative evaluation next to the binary quantitative system, we added detailed comments on the different items, making the evaluation transparent. To visualize the scoring system, we used color signaling, each item matched depending on the completion of the specific milestone with green (1) or red (0). A visualization tracking progress through data analytics giving alerts for required actions that have been widely used in learning contexts.[28–30] Summing up evaluation was documented numerically, visually, and with written comments.

Statistical analysis

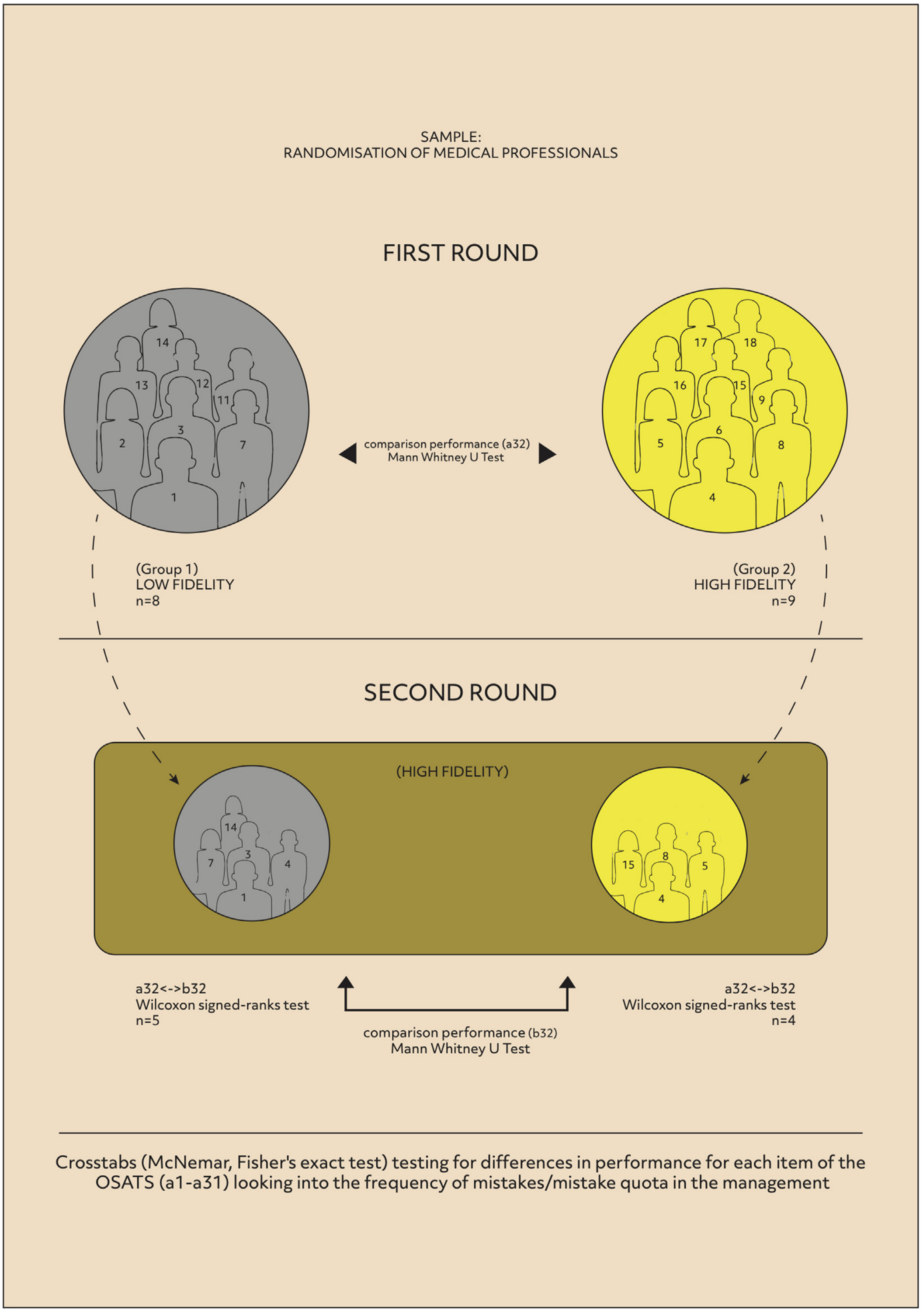
In our pilot study, we aimed to compare high- and low-fidelity setups regarding different aspects (see Figure 1). We analyzed the data of all 17 individual participants, of which 8 went through the low-fidelity simulation and 9 took the high-fidelity simulation defined as the first round.

In addition, we tested for the training effect, further investigating the data of all 9 participants (5 who underwent low-fidelity simulation and 4 who underwent high-fidelity simulation) who joined a second simulation round, then always as a high-fidelity setup.

Statistical tests were performed using IBM SPSS statistical software (version 29.0.0.0), and the P values of <.05 were considered significant. In addition, Microsoft Excel for Mac (version 16.66.1) was used.

For comparison between the 2 randomized groups ("low-fidelity setup" and "high-fidelity setup") and their general performance (maximum summary score of 31.0 points) in the first round of simulations, we used the Mann-Whitney U Test. Similarly, the general performance of all those individuals in the 2 different groups who participated in a second round of simulations was compared.

FIGURE 1
Study structure, methodology and statistical comparisons



Weyers. Reducing trainee mistakes. Changing to a high-fidelity simulation. Am J Obstet Gynecol Glob Rep 2024.

FIGURE 2
Objective Structured Assessment of Technical Skills Checklist for Postpartum Hemorrhage

POSTPARTUM HEMORRHAGE	
recognition of hemodynamic instability (blood pressure, pulse, oxygen saturation)	
recognition relevant blood loss / estimation blood loss	
asking for help	
delegation / leader function	
establishing vascular access	
blood sampling,blood gas analysis, hemoglobin	
provision of blood transfusion	
giving volume intravenously	
manual compression of the uterus	
emptying the bladder	
oxytocin infusion	
giving misoprostol / prostaglandin	
sulprostone or carbetocin (stopping oxytocin)	
tranexamic acid 2g	
fibrinogen: 2-4g	
planning of manual placenta residues removal	
succeeding in extraction of placenta tissue	
looking for trauma / vaginal examination	
examination via ultrasound	
recognition of bleeding is continuing despite drug treatment	
recognition continuing atony	
continued manual compression of the uterus	
giving blood products (other than transfusion of red blood cells)	
consider general anaesthesia	
consider chitosan coated tamponade (e.g. Celox)	
consider intrauterine balloon-tamponade/catheter (e.g. Bakri)	
consider/mention option of compression suture, ligature or hysterectomy	
Debriefing	
o empathy	
o explanation	
o any questions left?	
o team debriefing	
Total Time	
Total Score	

Weyers. Reducing trainee mistakes. Changing to a high-fidelity simulation. Am J Obstet Gynecol Glob Rep 2024.

Looking into the frequency of mistakes (mistake quota) in the management, the Fisher exact test was used, testing for differences in performance for each item of the OSATS between the 2 groups in the first round. The McNemar test was performed to detect the differences within a randomized group between the first round and second round of the simulations in each item of the performance.

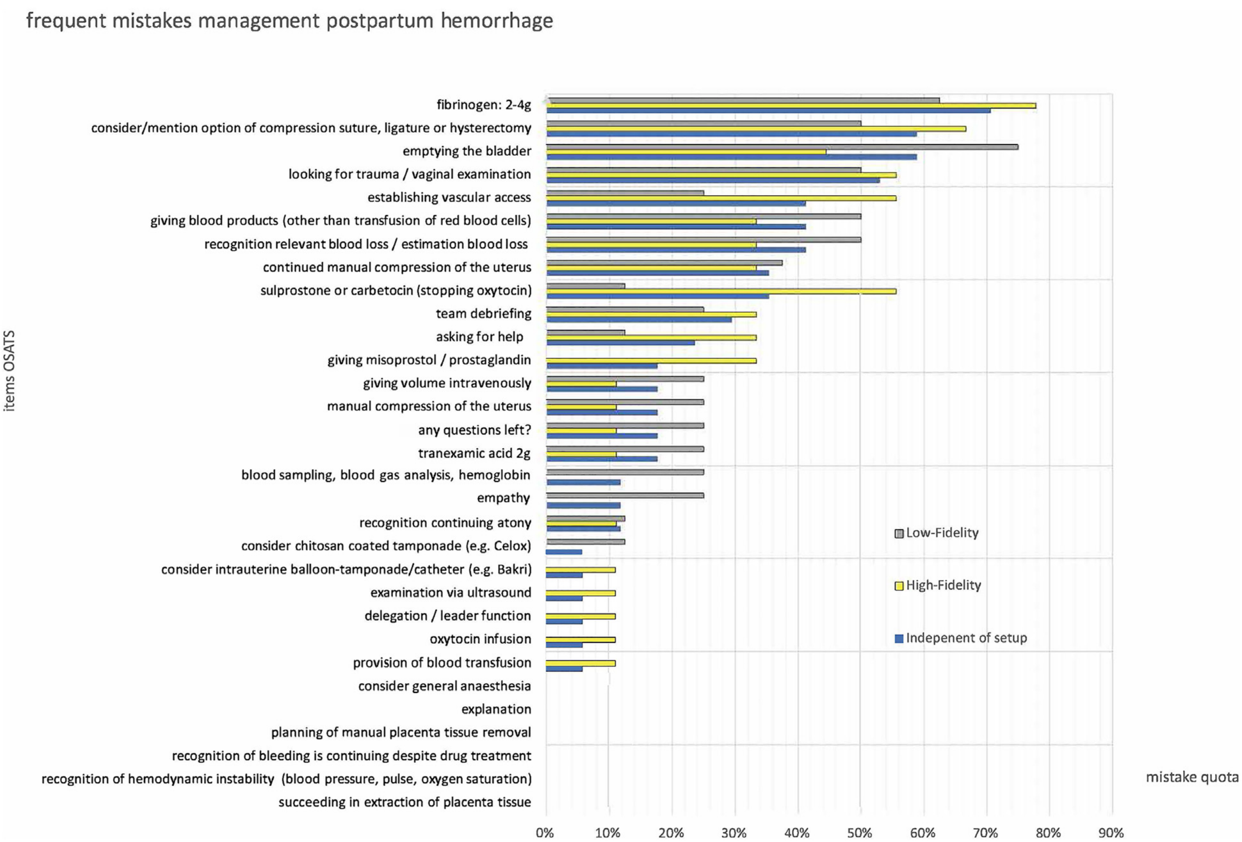
Testing for improvement (training effect) in all individuals that went through a second round, separated by low- and high-fidelity setups, we used the Wilcoxon signed-rank test.

Results

Primary results, first round

Comparing low- and high-fidelity groups in the first round, we found a similar scoring performance. The median scores were 24.5 (interquartile range [IQR], 21−28) in the low-fidelity group and 25.0 (IQR, 19−29) in the high-fidelity group. There was no significant difference in the general performance between the low- and high-fidelity groups looking at the first round (P=.96) and the second round (P=.29). There is no significant relation between setup and type or quota of mistake.

FIGURE 3
Incidence of mistakes in performance based on items on checklist



The *blue bar* indicates the incidence independent of the scenario setup, the *gray bar* indicates the low-fidelity setup, and the *yellow bar* indicates the high-fidelity setup.

Weyers. Reducing trainee mistakes. Changing to a high-fidelity simulation. Am J Obstet Gynecol Glob Rep 2024.

Primary results, second round, repeat simulation

However, there was a statistically significant difference in training effect when comparing total scores of performance (maximum points of 31.0) between the first round and the second round (*P*=.02; 24.7−27.2 of 31.0; average of 8.7%). When looking at each setup group independently, there was a statistically significant improvement in group 1 (participants 1, 2, 3, 7, and 14; low-fidelity setup in the first round and high-fidelity in the second round; *P*=.04) but no statistically significant improvement in group 2 (participants 4, 5, 8, and 15; high-fidelity setup in the first and second rounds; *P*=.27). The group that underwent both types of setups showed an average improvement of 12.9% (median, 9.7%; 24.4−28.4 of 31.0 points), whereas the group that just underwent 1 type of setup showed an average improvement of 2.4% (median, 3.2%; 25.0−25.8 of 31.0 points).

Secondary results

Common mistakes were defined as happening in >25% of the individuals. In general, when analyzing the PPH simulations in the first round by assessing each item required on the checklist, we found 10 items being neglected in >25% by all 17 residents, with 12 (70.6%) not considering giving fibrinogen; 10 (58.8%) not emptying the bladder or considering or mentioning the option of compression suture, uterine artery ligature, or hysterectomy; 9 (52.9%) not performing vaginal examination looking for trauma; 7 (41.1%) not estimating the blood loss, considering establishing intravenous lines, or considering giving blood products; 6 (35.3%) not considering the application of sulprostone or carbetocin while stopping oxytocin or continuing manual compression of the uterus; and 5 (29.4%) not planning or mentioning a team debriefing (see Figure 3).

In the top 3 mistakes comparing both setups in the first round, fibrinogen application; considering the option of compression suture, ligature, or hysterectomy; and looking for trauma through vaginal examination were neglected. In addition, looking at the items being neglected in >25%, there was a high overlap. An exception was the application of sulprostone or carbetocin after stopping oxytocin, which was more often neglected in the high-fidelity group.

Looking at both groups separately, in the low-fidelity group, 6 of 8 participants (75.0%) did not empty the bladder; 5 of 8 participants (62.5%)

neglected the application of fibrinogen; 4 of 8 participants (50.0%) did not estimate the blood loss or consider the option of compression suture, ligature, or hysterectomy and neglected vaginal examination; and 3 of 8 participants (37.5%) did not perform manual compression of the uterus.

In the high-fidelity group, 7 of 9 participants (77.8%) neglected the application of fibrinogen; 6 of 9 participants (66.7%) did not consider the option of compression suture, ligature, or hysterectomy; 5 of 9 participants (55.6%) did not establish intravenous lines or provide sulprostone or carbetocin and neglected vaginal examination; 4 of 9 participants (44.4%) did not empty the bladder; and 3 of 9 participants (33.3%) did not estimate the blood loss, call for help, give misoprostol or prostaglandin, continue manual compression, consider blood products, or mention a team debriefing. In general, when analyzing the mistakes, we observed a repetition of >50% of all mistakes on average.

Comment

Principal findings

There was a general improvement in performance in the second cycle of simulation and a significant training effect in the group that underwent repeat simulation from the initial low-fidelity system to the high-fidelity system compared with the group using the same high-fidelity setup. Simulation assessment can help identify mistakes for obstetrical trainees important to avoid in emergencies.

Results in the context of what is known

Looking into other studies that assess the management of PPH as 1 important key point, the estimation of blood loss is often proven to be underestimated.[16,31] Furthermore, late transfer to the operating room and delayed administration of blood products contribute to a bad outcome, likely resulting from underestimation of blood loss.[32] However, there is evidence that simulation training improves the assessment and timely intervention.[32,33]

Compared with traditional expert demonstration and "learning-by-doing" approaches, standardized hands-on simulations are more time and resource intensive. Therefore, increased costs, associated with the clinical implementation of these trainings should be justified by a high level of evidence. OSATS is particularly useful in providing individual and tailored feedback on trainee performance and can be used as a tool in training junior obstetricians to help identify deficits and shortcomings in their skills and techniques and to focus on improvement. Although assessment can be time-consuming and requires human and financial resources, effective evaluation methods improved through emerging technology, such as automated data collection and analysis with the help of AI, may alleviate these barriers. Virtual reality offers new opportunities, contributes to simulation training, and is an exciting emerging field.

Clinical implications

Emergencies being rare makes regular simulation the only way for proper preparation. Implementing simulation with OSATS based on direct and video-based feedback into resident programs could be used on an individual level for constructive feedback, identifying candidates to be invited for a repeat session and identifying individual knowledge deficits. Furthermore, it can be used as a tool to make training assessments more objective and, on a general level, to identify deficiencies in training programs and draw conclusions for effective teaching.

The observed repetition of >50% of all mistakes on average could be an indicator of not only a random human mistake but also a knowledge gap or not correctly internalized algorithm to deal with the emergency. When such a repeated mistake is identified and efforts are placed into relearning or correcting this mistake through training, this could have great potential to positively affect the quality of care.

Our research community should take into account that the quality spectrum of simulation training might vary widely. Moreover, we suggest implementing a high-quality, standardized training model based on OSATS to make simulation training easier to compare research contexts and to contribute to a higher level of evidence in the future. Our study provides such an assessment protocol for others to use. As emergencies cannot be planned, there is a natural fluctuation and cause dependency. However, simulation training can be planned to include the individualized need for repetition.

Research implications

Emergencies being relatively rare make it difficult, but not impossible, to test the effectiveness of training experience in a prospective controlled trial. More studies should be conducted to provide additional information and material for simulation-based interventional programs.

Strength and limitations

Limitations

This was a prospective randomized pilot study where the participant population was limited. Although there may be an element of interobserver variability, the detailed transcription of the video material and the traceability and reproducibility regarding the assessment counterbalance this.[24] We did account for intraobserver variability by filming the participants and having the examiner score the same performance repeatedly.

Strengths

With a well-structured approach based on a consistent format and strict adherence to a script, our study assessed the specific shortcomings of medical professionals in the management of PPH. Because of the COVID-19 pandemic, we designed a 1:1 simulation scenario instead of a team simulation to keep infection risks as low as possible. When the participants asked to involve more team members as part of the simulation, no help came, as defined in the simulation setup. This presented a possible worst-case scenario, with lacking personal resources. We consider this as a strength of the study.

Conclusions

The training effect in the management of PPH was higher when changing from a low-fidelity setup to a high-fidelity setup. A key finding was the identification and classification of mistakes through simulation assessment (see Figure 3).

In general, the top 3 mistakes were the neglect of fibrinogen application; not considering the option of compression suture, ligature, or hysterectomy; and not looking for trauma through vaginal examination.

In addition, the remarkable repetition of more than 50% of all mistakes in the second round suggests the importance and potential of feedback to intervene.

Our study presents a scenario script and an OSATS checklist for teaching and evaluating the management of PPH to identify pitfalls and learning gaps through simulation assessment. ■

CRediT authorship contribution statement

Aino Ritva Weyers: Writing – review & editing, Writing – original draft, Visualization, Software, Project administration, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Gabriel von Waldenfels:** Writing – review & editing, Supervision. **Pimrapat Gebert:** Writing – review & editing, Supervision. **Wolfgang Henrich:** Supervision. **Larry Hinkson:** Writing – review & editing, Writing – original draft, Supervision, Project administration, Methodology, Investigation, Conceptualization.

REFERENCES

1. Say L, Chou D, Gemmill A, et al. Global causes of maternal death: a WHO systematic analysis. Lancet Glob Health 2014;2:e323–33.

2. Greene RA, McKernan J, Manning E, et al. Major obstetric haemorrhage: incidence, management and quality of care in Irish maternity units. Eur J Obstet Gynecol Reprod Biol 2021;257:114–20.

3. Flood M, McDonald SJ, Pollock W, Cullinane F, Davey MA. Incidence, trends and severity of primary postpartum haemorrhage in Australia: a population-based study using Victorian Perinatal Data Collection data for 764 244 births. Aust N Z J Obstet Gynaecol 2019;59:228–34.

4. Reale SC, Easter SR, Xu X, Bateman BT, Farber MK. Trends in postpartum hemorrhage in the United States from 2010 to 2014. Anesth Analg 2020;130:e119–22.

5. Ladfors LV, Muraca GM, Zetterqvist J, Butwick AJ, Stephansson O. Postpartum haemorrhage trends in Sweden using the Robson ten group classification system: a population-based cohort study. BJOG 2022;129:562–71.

6. Lutomski JE, Byrne BM, Devane D, Greene RA. Increasing trends in atonic postpartum haemorrhage in Ireland: an 11-year population-based cohort study. BJOG 2012;119:306–14.

7. Knight M, Callaghan WM, Berg C, et al. Trends in postpartum hemorrhage in high resource countries: a review and recommendations from the International Postpartum Hemorrhage Collaborative Group. BMC Pregnancy Childbirth 2009;9:55.

8. van Stralen G, von Schmidt Auf Altenstadt JF, Bloemenkamp KW, van Roosmalen J, Hukkelhoven CW. Increasing incidence of postpartum hemorrhage : the Dutch piece of the puzzle. Acta Obstet Gynecol Scand 2016;95:1104–10.

9. Sheldon WR, Blum J, Vogel JP, et al. Postpartum haemorrhage management, risks, and maternal outcomes: findings from the World Health Organization Multicountry Survey on Maternal and newborn Health. BJOG 2014;121(Suppl1):5–13.

10. Rizvi F, Mackey R, Barrett T, McKenna P, Geary M. Successful reduction of massive postpartum haemorrhage by use of guidelines and staff education. BJOG 2004;111:495–8.

11. Cantwell R, Clutton-Brock T, Cooper G, et al. Saving Mothers' Lives: reviewing maternal deaths to make motherhood safer: 2006-2008. The eighth report of the confidential enquiries into maternal deaths in the United Kingdom. BJOG 2011;118(Suppl1):1–203.

12. Bouvier-Colle MH, Saucedo M, Deneux-Tharaux C. CNEMM. [The confidential enquiries into maternal deaths, 1996-2006 in France: what consequences for the obstetrical care?]. J Gynecol Obstet Biol Reprod (Paris) 2011;40:87–102.

13. Berg CJ, Harper MA, Atkinson SM, et al. Preventability of pregnancy-related deaths: results of a state-wide review. Obstet Gynecol 2005;106:1228–34.

14. Farquhar C, Sadler L, Masson V, Bohm G, Haslam A. Beyond the numbers: classifying contributory factors and potentially avoidable maternal deaths in New Zealand, 2006-2009. Am J Obstet Gynecol 2011;205. 331.e1–8.

15. Annecke T, Lier H, Girard T, et al. Peripartale Blutungen, Diagnostik und Therapie: Update der S2k-Leitlinie AWMF 015/063 vom August 2022 [Peripartum hemorrhage, diagnostics and treatment: Update of the S2k guidelines AWMF 015/063 from August 2022]. Anaesthesiologie 2022;71:952–8.

16. Anderson JM, Etches D. Prevention and management of postpartum hemorrhage. Am Fam Physician 2007;75:875–82.

17. Merién AER, Van De Ven J, Mol BW, Houterman S, Oei SG. Multidisciplinary team training in a simulation setting for acute obstetric emergencies: a systematic review. Obstet Gynecol 2010;115:1021–31.

18. Fransen AF, van de Ven J, Banga FR, Mol BWJ, Oei SG. Multi-professional simulation-based team training in obstetric emergencies for improving patient outcomes and trainees' performance. Cochrane Database Syst Rev 2020;12:CD011545.

19. Ameh CA, Mdegela M, White S, van den Broek N. The effectiveness of training in emergency obstetric care: a systematic literature review. Health Policy Plan 2019;34:257–70.

20. Artyomenko VV, Nosenko VM. Anaesthesiologists' simulation training during emergencies in obstetrics. Rom J Anaesth Intensive Care 2017;24:37–40.

21. Brogaard L, Glerup Lauridsen K, Løfgren B, et al. The effects of obstetric emergency team training on patient outcome: a systematic review and meta-analysis. Acta Obstet Gynecol Scand 2022;101:25–36.

22. Gavin NR, Satin AJ. Simulation training in obstetrics. Clin Obstet Gynecol 2017;60:802–10.

23. Hatala R, Cook DA, Brydges R, Hawkins R. Constructing a validity argument for the objective structured assessment of technical skills (OSATS): a systematic review of validity evidence. Adv Health Sci Educ Theory Pract 2015;20:1149–75.

24. Martin JA, Regehr G, Reznick R, et al. Objective structured assessment of technical skill (OSATS) for surgical residents. Br J Surg 1997;84:273–8.

25. Green W, Shahzad MW, Wood S, et al. Improving junior doctor medicine prescribing and patient safety: an intervention using personalised, structured, video-enhanced feedback and deliberate practice. Br J Clin Pharmacol 2020;86:2234–46.

26. Giambrone J, Miltenberger RG. Using video self-evaluation to enhance performance in competitive dancers. Behav Anal Pract 2020;13:445–53.

27. Winfrey ML, Weeks DL. Effects of self-modeling on self-efficacy and balance beam performance. Percept Mot Skills 1993;77:907–13.

28. Tally S. Signals tells students how They're doing even before the test.Phys.org 2009. Available at: https://phys.org/news/2009-09-students-theyre.html. Accessed March 11, 2024.

29. Lederman R, Constantinidis D, Linden T, et al. Using a traffic light system to provide feedback to IS masters students. Conference Paper at International Conference on Information Systems: transforming society with digital innovation, South Korea 2017; Published 2018; Available at: https://www.researchgate.net/publication/321866343_Using_a_Traffic_Light_System_to_Provide_Feedback_to_IS_Masters_Students. Accessed March 11, 2024.

30. Arnold KE, Pistilli MD. Course signals at purdue: using learning analytics to increase student success. Conference Paper at LAK: Proceedings of the 2nd International Conference on Learning Analytics and Knowledge; April 2012, p267–270; Available at: https://doi.org/10.1145/2330601.2330666; Accessed March 11, 2024.

31. Bose P, Regan F, Paterson-Brown S. Improving the accuracy of estimated blood loss at obstetric haemorrhage using clinical reconstructions. BJOG 2006;113:919–24.

32. Maslovitz S, Barkai G, Lessing JB, Ziv A, Many A. Improved accuracy of postpartum blood loss estimation as assessed by simulation. Acta Obstet Gynecol Scand 2008;87:929–34.

33. Toledo P, McCarthy RJ, Hewlett BJ, Fitzgerald PC, Wong CA. The accuracy of blood loss estimation after simulated vaginal delivery. Anesth Analg 2007;105:1736–40.