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ORIGINAL ARTICLE

Repeated simulation-based training for performing general anesthesia for emergency cesarean delivery: long-term retention and recurring mistakes

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ABSTRACT
Background: The percentage of women undergoing cesarean delivery under general anesthesia has significantly decreased, which limits training opportunities for its safe administration. The purpose of this study was to evaluate how effective simulation-based training was in the learning and long-term retention of skills to perform general anesthesia for an emergent cesarean delivery.
Methods: During an eight-week obstetric anesthesia rotation, 24 residents attended lectures and simulation-based training to perform general anesthesia for emergent cesarean delivery. Performance assessments using a validated weighted scaling system were made during the first (pre-test) and fifth weeks (post-test) of training, and eight months later (post-retention test). Resident's competency level (weighted score) and errors were assessed at each testing session. Six obstetric anesthesia attending physicians, unfamiliar with the simulation scenario, generated a mean attendings' performance score. The results were compared.
Results: At one week of training, residents' performance was significantly below mean attendings' performance score (pre-test: 135 ± 22 vs. 159 ± 11, $P = 0.013$). At five weeks, residents' performance was similar to mean attendings' performance score (post-test: 159 ± 21) and remained at that level at eight months (post-retention test: 164 ± 16). Of the important obstetric-specific tasks, left uterine displacement was missed by 46% of residents at eight months.
Conclusion: Following lectures and simulation-enhanced training, anesthesia residents reached and retained for up to eight months a competency level in a simulator comparable to that of obstetric anesthesia attending physicians. Errors in performance and missed tasks may be used to improve residency training and continuing medical education.

Keywords: General anesthesia; Cesarean delivery; Simulation-based training

Introduction

The proportion of women undergoing cesarean delivery has increased significantly over the past decades,[1] while over a similar period the use of general anesthesia (GA) for cesarean delivery has decreased significantly.[2] There is concern that obstetric anesthesia training may not provide sufficient opportunities to master the technique.[3–5] Simulation-based training has been recommended to provide additional training opportunities.[6,7]

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Scavone et al. used a high-fidelity patient simulator to create a scenario for anesthesia residents on how to perform a GA for emergency cesarean delivery. A scoring tool was validated to evaluate the performance of residents during the scenario (Appendix A).[8] In a follow-up trial, the same group confirmed that this focused high-fidelity obstetric simulation resulted in improved competency 6–9 weeks after training than a non-obstetric scenario of rapid sequence induction for general anesthesia.[9]

Our department introduced a simulation scenario using the validated scoring system for second year anesthesia residents in 2010.[8] However, a score that measured competency in performing safe GA for urgent cesarean delivery was not determined, and it was unclear whether residents retain competency over time. Therefore, a longitudinal observational study was designed to both identify a mean attendings' performance score (MAPS) that assessed experts in the same simulation scenario, and to determine what levels residents reach and retain. Errors and areas of poor retention were identified to improve education.

Methods

This study was approved by the Institutional Review Board of the Office for Protection of Research Subjects of the University of Washington (IRB# 42712). In their second year of anesthesia training, 24–28 residents rotate through the Labor and Delivery Unit of the University of Washington Medical Center (UWMC). This is a low-volume, high-risk obstetric unit with 800 cesarean deliveries annually, of which up to 90% are unscheduled and only 3–5% are performed under GA; on average, each resident performs 1–2 GA for emergency cesarean delivery during their residency. The UWMC obstetric anesthesia rotation is of eight weeks duration, with four residents per rotation. Residents are supervised during day and night shifts by a team of obstetric anesthesia attending physicians (attendings). At the start of the rotation, residents are given reading material and attend a 45-min interactive presentation on how to perform a GA for an emergent cesarean delivery, and since 2010 also undergo a simulation-based training during the first week of the rotation. Simulations are conducted in a purpose-built simulated operating room environment that uses a high-fidelity computerized life-size human mannequin (Laerdal SimMan 3G, Laerdal Medical AS, Stavanger, Norway).

During 2010–2011, 24 consecutive second year anesthesia residents were informed that they would undergo simulation training and testing on how to perform a GA for an emergency cesarean delivery. Tests were performed during the first (pre-test) and fifth weeks (post-test) of the rotation, and a further test was performed eight months after the obstetric anesthesia rotation (retention post-test). Informed consent was given for use of anonymized data for educational research purposes; non-acceptance did not alter the teaching curriculum. Residents were not informed that the scenario would be the same at each session, nor that the scoring system was a validated tool that was published and accessible online. Residents were not given a copy of the list or their final score. Residents were further asked not to discuss the simulation session or the scenario itself with each other and were informed that their scores would not be used in any formal or informal evaluation of their clinical competence.

At the start of the session, each resident indicated the number of simulation trainings and rapid-sequence inductions that they had performed in non-obstetric and obstetric patients (none, 1–5, 6–10, 11–15, 16–20, > 20), and rated their comfort performing a GA for an emergency cesarean delivery using an 11 point numerical rating scale (0 = not at all confident and 10 = extremely confident).

The training session started with an orientation to the simulator environment. The scenario started when the resident was paged to the simulation room where the obstetrician (training evaluator BR or CO) and a nurse (a staff member who also provided assistance to the resident), were waiting. The obstetrician called out the scenario: a woman in labor with an umbilical cord prolapse who required emergency cesarean delivery. A medical history was provided only if the resident specifically asked for it. A photograph of a patient's airway was presented if the resident enquired about airway status. Residents were expected to perform an equipment availability check followed by tasks that included seven specific to obstetric anesthesia (obtain an obstetric history, provide left uterine displacement, verify obstetric team readiness, notify obstetric team to proceed once airway secured, provide adequate O_2:N_2O ratio, timely administration of oxytocin, and appropriate reduction of inhaled volatile anesthetic).

After the scenario the evaluator and resident debriefed the session and reviewed performance on the 48 item scoring system. Each task is weighted on a scale of importance from 1 to 5, resulting in a maximal score of 198.5 points (Appendix A).[9] The importance of each missed task and error was specifically discussed with the resident. The score was calculated to derive a resident's weighted score. Scored data sheets were stored at the simulation center.

Obstetric anesthesia attending physicians who were not familiar with the scenario or simulation protocol were evaluated in the same way. The mean score of the attendings yielded the MAPS. The physicians are either fellowship trained in obstetric anesthesia or dedicate 50–100% of their clinical time to obstetric anesthesia. To be eligible for participation, attendings had to be familiar with the simulation environment in the same way as the residents, but unfamiliar with this specific scenario or the simulation protocol itself.

Statistical analysis

Sample size calculation was based on pilot data from eight second year anesthesia residents from 2009 to 2010, evaluated at one-week during their simulation-based training on the obstetric anesthesia rotation and all six eligible obstetric anesthesia attendings. Assuming an α-value of 0.01 and a β-value of 0.99, a total of 22 trainees was needed to show a progression from the mean residents score of 131 ± 13 during pilot sampling to the obstetric anesthesia attending competence level score of 159 ± 11. All 24 residents in 2010 were enrolled.

Examinations were graded by a single instructor (either BR or CO) and videotaped. Ten randomly selected sessions for each instructor (total of 20/78 sessions, 25.6%) were re-scored by the other rater to estimate inter-rater reliability. The rater reviewing video recordings was unaware of both the score given by the instructor and which session was evaluated (pre-test, post-test or retention post-test). Inter-rater reliability was estimated using the Cohen's chance adjusted Kappa (K_c) coefficient.

Overall mean weighted scores of residents, and frequency of each task successfully performed were compared over time with one-way ANOVA. If significance level was reached, differences were evaluated with Newman-Keul's test. MAPS and frequency of each task successfully performed by attendings were compared to results obtained from residents using Student's t-test. To use the five-week post-test score as a predictor for retaining competency level at eight months, mean retention post-test scores of residents achieving MAPS at five weeks (considered a success at five weeks) were compared with eight-month retention post-test scores of residents not reaching MAPS at five weeks (considered a fail at five weeks) by using Fisher's exact test. The odds ratio (OR) of success at eight months with history of success at five weeks/success at eight months with history of failing at five weeks was calculated. Significance level was defined as $P < 0.05$. Descriptive data are presented as mean ± standard deviation (SD), percentage or median and interquartile range [IQR], as appropriate. Statistical analysis was conducted on STATISTICA version 10 (Statsoft Inc., Tulsa, OK, USA).

Results

All 24 residents completed each training session (pre-test, post-test and retention post-test) and agreed to have their data used for research purposes. The number of previous rapid-sequence inductions performed in pregnant and non-pregnant patients prior to each training session is shown in Table 1. Inter-rater reliability measured by the mean kappa coefficient was high ($K_c = 0.92$) across the 48 checklist items.

Pre-test scores were significantly lower than post-test scores (135 ± 22 vs. 159 ± 21, respectively, $P < 0.01$) and retention post-test scores (164 ± 16, $P < 0.01$). There was no difference between post-test and retention post-test (Fig. 1). Overall, pre-test scores were significantly lower than MAPS ($P = 0.013$). Residents' scores were the same as MAPS level at five weeks ($P = 0.99$) and eight months ($P = 0.53$).

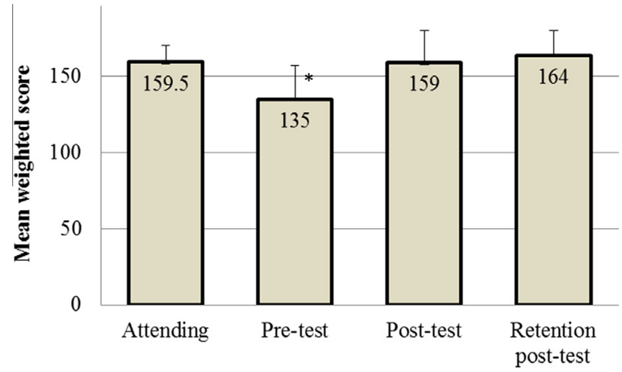

Fig. 1 Total mean weighted scores of six supervising attending physicians in the field of obstetric anesthesiology and 24 second year anesthesia residents undergoing simulation-based training at one week (pre-test), five weeks (post-test) during OB-anesthesia rotation and after eight months (retention post-test). Error bars represent standard deviation from the mean ± SD. $^{*}P < 0.05$ comparing pre-test to attendings', post-test and retention post-test mean scores.

At one week, four residents (17%) achieved MAPS, at five weeks 15 residents (63%) achieved MAPS and at eight months 16 residents (67%) reached MAPS. Seventy-five percent of residents that had reached MAPS at five weeks maintained this level of performance at eight months. Four of the nine residents that had not achieved MAPS at five weeks reached it at eight months (OR 3.8, $P = 0.099$).

Twenty of the 48 items evaluated were performed by >95% of residents (23 of 24) eight months after the obstetric anesthesia rotation (Table 2). Nine of the 22 highly weighted items were missed by some residents (Table 3), and none of the seven obstetric anesthesia specific tasks was successfully performed by each resident. Left uterine displacement, verifying obstetric team readiness and notifying the obstetric team to proceed were missed by 46%, 33% and 17% residents, respectively.

Performance of each listed task for each session (pre-test, post-test, and retention post-test) is presented in Appendix A. Only four tasks were performed consistently: administration of induction agent, administration of succinylcholine, direct laryngoscopy, passing of the tracheal tube. Pre-operative assessment was performed poorly by residents at one week of training, but almost all tasks had significantly improved at five weeks and eight months. Almost 50% of residents

Table 1 **Clinical and simulation experience and self-confidence level of residents before simulation training**

	Pre-test	Post-test	Retention post-test
Previous RSI in non-pregnant patients (n)	>20	>20	>20
Previous GA for cesarean delivery (n)	0 [0–1]	2 [2–3]	2 [2–3]
Number of previous simulations (n)	2 [1–4]	3 [1–5]	4 [2–6]
Self-confidence level	4 ± 2	7 ± 1	7 ± 1

Data are number, median [IQR] or mean ± SD.; RSI: rapid sequence induction; GA: general anesthesia.

Table 2 Simulation testing results comparing attendings with residents eight months after obstetric anesthesia rotation

	Attending Physician (n=6)	Retention post-test (n=24)		Attending Physician (n=6)	Retention post-test (n=24)
Introduce self	100	96			
Medication history	100	92	Administer induction agent	100	100
Previous anesthetic / family history	67	42	Administer succinylcholine	100	100
Allergy history	83	88	Wait for medication effect	100	88
Perform airway exam	67	67	Direct laryngoscopy	100	100
			Pass tracheal tube	100	100
Preoperative patient care			Inflate cuff	100	100
Administer sodium citrate	67	92	Confirm end-tidal CO_2	83	100
Administer 100% O_2 by mask	100	96	Release cricoid pressure	100	96
Ensure working iv catheter	50	67	Confirm bilateral breath sounds	17	46
Apply blood pressure cuff	100	100	Secure tracheal tube	83	88
Apply pulse oximeter	100	100			
Apply electrocardiogram	100	100	***Intraoperative management before delivery***		
Quick circuit check	33	63	Initiate mechanical ventilation	100	100
Tracheal tube	100	92	Appropriate tidal volume/ respiratory rate	100	100
Syringe for tracheal tube	100	92	Apply nerve stimulator	17	8
Stylet	100	96	Inhaled agent ≥ 1 MAC	100	79
Laryngoscope light intact	50	96	Protect eyes	33	29
Functional suction	0	71	Orogastric tube placed for suction	0	21
			Esophageal stethoscope placed	0	13
Induction and intubation			Temperature monitored	0	0
Pulse oximeter audible	100	100			
Blood pressure cycling	100	88	***Intraoperative management after delivery***		
Electrocardiogram functioning	100	100			
Apply cricoid pressure	100	96	Administer opioid, N_2O, hypnotic, paralytic as needed	100	96

Highly weighted tasks (5 points) missed by second year anesthesia residents eight months post rotation are heavily shaded. Tasks performed by <95% of residents eight months post rotation are lightly shaded and task performed by >95% of residents at eight months post rotation have no shading. MAC: minimum alveolar concentration.

repeatedly missed providing left uterine displacement at five weeks and at eight months.

One third of residents did not check the anesthetic circuit or confirm presence of a working suction before induction of anesthesia. Obstetric anesthesia attending physicians performance was below that of residents. When anesthesia was induced, inappropriate communication with the obstetric team, failure to confirm obstetric team readiness and/or notification for the obstetric team to proceed were noted (Table 3). More than 50% of participants, including attendings, did not check for bilateral breath sounds during each training session. Intraoperatively, placement of an orogastric tube, esophageal stethoscope and temperature probe were consistently omitted by all attendings and residents at the pre-test evaluation, and by a significant percentage of residents at five weeks and eight months. At one and five weeks, as well as at eight months, >20% of residents neither administered fractional inspired oxygen content (FiO_2) $\geqslant 0.5$, nor did they provide inhaled anesthesia with >1 MAC before delivery. At one week, 62% of residents did not reduce inhalation anesthetic after delivery, a task that was still missed by 21% of residents at eight months.

Discussion

This small observational longitudinal study showed that residents in a simulation environment reach a competency level in performing GA for emergency cesarean delivery comparable to that of obstetric anesthesia attendings. This level of competency was maintained at eight months. An analysis of errors and missed tasks showed that a number specific to obstetric anesthesia were not consistently retained at the end of the rotation or later.

A recently published meta-analysis demonstrated that simulation-based training in anesthesiology

Table 3 Percentage of obstetric anesthesia specific tasks successfully performed by attendings and residents undergoing simulation training eight months after completing obstetric anesthesia training

	Attending Physicians (n=6)	Retention post-test (n=24)
Obtain pertinent obstetric history	100%	83%
Provide left uterine displacement	67%	54%
Verify obstetric team readiness	100%	67%
Notify obstetric team to proceed	100%	83%
$FiO_2 \geq 0.5$ ($N_2O:O_2$ 50:50)	33%	71%
Oxytocin added to intravenous fluids	100%	92%
Inhaled Agent ≤ 0.5 MAC	67%	79%

Data are percentage. Highly weighted task (5 points) missed by second year anesthesia residents at retention post-test are heavily shaded. Low weighted tasks missed by second year anesthesia residents at retention post-test are lightly shaded. FiO_2: inspired oxygen concentration; MAC: minimum alveolar concentration.

improves clinical skills, behavior and improves retention of skill and knowledge.[10] Simulation-based training significantly improves residents' compliance with complex airway management guidelines,[11,12] and is likely to improve patient care.[13] It has been recommended to provide exposure to performing a safe GA for emergency cesarean delivery.[7] Our residents underwent a published simulation training scenario,[8] and their performance was measured on a weighted scoring system developed via Delphi technique,[14] and the scoring system was further subjected to validity and reliability tests.[8,9]

Clinical skills assessed in the simulator environment have repeatedly shown a significant difference in competency between attendings, residents and medical students.[15–18] This study used obstetric anesthesia attendings as a benchmark to define a competency level, and the results showed that the performance of residents at one week was below that of the obstetric anesthesia attendings, but at five weeks had reached a comparable score, and suggests that high-fidelity obstetric simulation training may enhance learning as previously described.[9] Residents' mean scores were maintained after eight months, indicating retention of competency. However, the fact that residents had accumulated experience over the eight-month study period and had performed rapid-sequence inductions in other clinical situations will have improved skill retention; it was not solely attributable to the simulation-based training. An attempt was made to determine the predictive value of scores at five weeks for performance at eight months: residents reaching MAPS at five weeks were more likely to retain MAPS at eight months compared to residents who did not. However, one in four residents who achieved MAPS at five weeks failed to do so at eight months, suggesting that the post-test is unreliable in predicting who will perform favorably in retention sessions. A model to predict individual retention and duration of retention has yet to be developed,[19–21] but there is some evidence that simulation-based assessment is a valid method for identifying critical gaps in performance.[22]

Mean scores are based on the total score achieved. No account is taken of the number of highly-weighted tasks omitted or achieved during testing. Analysis of recurring errors and missed tasks is important because frequently missed tasks can be used as an educational tool. Performance of obstetric anesthesia specific tasks was inconsistent, with particular concern for tasks such as providing left uterine displacement, verifying obstetric team readiness and notifying the obstetric team to proceed. Anesthesiologists who do not work regularly in an obstetric unit may need to be reminded of the importance of these tasks.

MAPS have been used as a benchmark in a variety of simulation studies.[15–17] In our study, MAPS identified variances in our own clinical practice. Although the obstetric simulation scenario was new to the attending physicians, repeated simulation training could have improved their scores as for the residents. However, attendings are familiar with the simulation environment because they participate in them regularly, and their scores are likely to reflect their true performance. The scoring system was validated and based on the recommendations of obstetric anesthesiologists in university or private practice in the USA.[8] Although unexpected, it was not entirely surprising that obstetric anesthesia attendings failed to perform an equipment check; this task is typically performed by residents at our institution. Nevertheless, missed tasks and the variability of practice among attendings were noted with some concern, and resulted in plans to standardize future practice. The obstetric simulation training is now included in the continuing medical education of attendings.

This study has several limitations. Residents were asked not to discuss the scenario or the methodology used in the study, but conversations may have taken place that could have introduced bias. However, neither scores nor self-confidence levels changed over the trial period, leading us to believe that such learning did not take place. Residents were scored only during direct observation and not via video recordings, when sub-optimal camera views of anesthetic management might have hampered scoring. Each resident was evaluated by one instructor. Reliability between instructor scores was assessed by randomly rescoring 25% of training sessions, and was high, consistent with reports applying a similar rating system.[14–18] The scoring system was simple because the outcomes assessed were binary. In the original use of this scoring system, second year anesthesia residents underwent repeated simulation training at six to nine weeks.[19] Their scores averaged 155 ± 19, the same as our residents (post-test score 159 ± 21) evaluated with the same checklist. Inter-rater variability appears low even across different institutions. The study was conducted at a single institution and MAPS was determined using a single group of obstetric anesthesia attendings. Obstetric anesthesiologists at UWMC have trained in a variety of institutions in the USA and Europe, and their training is likely to represent more than the local standards of a single institution.

The question remains whether performance in the simulator accurately represents performance in real life. The use of simulation-based training has been shown to improve quality of patient care and outcomes in a variety of medical specialties,[23–25] and it will be for future studies to determine if simulation-based training can improve the performance of GA for cesarean delivery and the quality of patient care.

In conclusion, based on two repeated sessions of high-fidelity simulation training five weeks and eight months apart, anesthesia residents achieve and retain a simulator competency similar to that of their supervisors. Frequent errors and missed tasks in both obstetric anesthesia specific and general tasks offer opportunities to improve training.

Disclosure

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Appendix A. Supplementary data

Supplementary data associated with this article can be found, in the online version, at http://www.dx.doi.org/10.1016/j.ijoa.2014.04.008.