

Appendix A

Development of Educational Interventions and Measurement Instruments

Traditional Lecture

The 60-minute lecture was delivered by A.J.L., during week 3 of CA-1 year. The material described the essential concepts of crisis resource management for anesthesiologists[1, 2], with the case illustration being the performance of general anesthesia for emergency cesarean delivery, in a parturient with umbilical cord prolapse. The relevant physiologic changes of pregnancy and their unique anesthetic implications were incorporated into the content.

Serious Game Development

Two novel serious games were developed:

- (1) EmergenCSim™, where the player must perform general anesthesia for emergency cesarean delivery in the setting of umbilical cord prolapse (Figure 2A) - played by the intervention group only in month 1 of CA-1, then by both intervention and control groups later in the academic year.
- (2) A “sham” (non-content specific) anaphylaxis video game, where the player must treat a non-pregnant patient experiencing severe anaphylaxis following antibiotic administration - played only by the control group in month 1 of CA-1.

A computer-generated electronic debriefing script, displaying the total score and a log of correct actions (indicated by green bullets) and missed steps (indicated by red bullets) accompanied by explanations, were presented at the conclusion of game play (Figure 2B).

The software for the EmergenCSim™ and anaphylaxis games were both built upon an existing platform created by Medusims® (Paris, France), using the Unity5™ 3-D real time development platform (Unity Technologies, San Francisco, CA). The 3-D graphic interface virtually reproduces the environment of a United States-based operating room. Changes in vital signs are achieved using a Medusims® human physiology engine. Input and navigation through the games are mouse-controlled. The subject experiences all action from the viewpoint of the protagonist,

who has a 360° view of the operating room and the ability to interact with other avatars via click and command icons. All scripted dialogue is experienced in both audible form and as a text display to enhance clarity, and to alleviate cognitive load for the player. A 3-minute video tutorial, which describes how to navigate and perform actions within the SGs,

was viewed, to orient participants to the game interface. The tutorial may be viewed via this link:

<https://youtu.be/LP6WwQHPQ4U>.

Non-content Specific Game on Anaphylaxis

The expected actions in the anaphylaxis game were based on recommendations in the literature [3]. The player is required to evaluate a non-pregnant woman who has developed respiratory distress shortly after beginning to receive surgical antibiotic prophylaxis. Avatars developed included the patient and circulating nurse, who reports to the player that the patient became dyspneic after beginning to receive the antibiotic infusion. The player is expected to diagnose anaphylaxis, discontinue antibiotic administration, provide supplemental oxygen, and administer intravenous epinephrine and fluid boluses. The maximum duration of the game is 10 minutes; the player is only allowed to exit earlier if, at minimum, one dose of epinephrine and an intravenous fluid bolus have been initiated. A brief structured electronic debrief is provided at the conclusion of game play. The non-content specific game was created to avoid the control group of learners being disadvantaged by never having experienced the game interface. No scoring tool was developed for this game.

EmergenCSim™

The written prebrief for EmergenCSim™ explains that the player is a CA-1 resident during their initial obstetric anesthesia rotation and that they have been paged to go emergently to the obstetric operating room. Upon entering the simulated operating room, their avatar is greeted by the obstetric surgeon positioned next to the patient on the operating table, with a vaginally-placed hand elevating the fetal head to relieve pressure on the umbilical cord. The obstetrician hurriedly reports that there is fetal bradycardia secondary to vaginal prolapse of the umbilical cord and the parturient needs to be immediately anesthetized for emergency cesarean delivery.

The expected actions for this scenario were adapted from a previously validated 52-item behavior checklist and weighted objective scoring system developed by Scavone et al.[4] in the Table below. The scoring scheme was modified based on the consensus of experts (A.J.L., S.R.G. and R.L.), to adjust selected scores to reflect current practice - performing left uterine displacement (decrease from 5 to 2 points), administration of sodium citrate (decrease from 4 to 2 points), and elimination of the expectation to place an esophageal stethoscope (decrease from 2 points to zero). Two new actions were added - “call for help” (3 points) and “prepare medications” (2 points). The total achievable score within the game is 196.5.

For EmergenCSim™, avatars developed included the parturient, obstetrician, circulating nurse and anesthesiology attending physician. To simulate the stress of a real-world scenario and enhance the sense of realism during the game, a pop-up with the obstetric surgeon’s image, and audio with associated text asking whether the patient had been anesthetized yet would intermittently flash on the screen. The player is obligated to click “yes” or “no” to close the box, in order to proceed with the game. The player is able to interact with the parturient and obstetrician with a limited script. To perform rapid sequence intubation in the SG the player is given 2 attempts to use a drag and drop menu (with actions listed such as “apply cricoid pressure” or “inflate pilot balloon”) to create the correct sequence of actions.

The game can be played for a maximum of 10 minutes, but the player can voluntarily exit only after playing for a minimum of 5 minutes. At the end of gameplay an electronic debrief page is provided [5].

Serious Game Pilot testing

Software crash reports from pilot testing by the 2016 CA-1 class were used to institute modifications. A needs assessment of EmergenCSim™, using semi-structured cognitive interviews with the 3 highest and lowest scoring residents, was performed to determine what they most liked and disliked about the game experience, and to give open-ended feedback. The most common criticism was unfamiliarity with the game interface, which prompted our development of the video tutorial.

High-Fidelity Simulation Development

The content for the mannequin-based HFS scenario was designed to be as identical as possible to the EmergenCSim™ digital simulation, with the same actions (behaviors) scored by raters of the videotaped scenario as within the game.

Immediately prior to the HFS, the learner received a scripted verbal prebrief by A.J.L. where they were reassured that performance assessment would be used solely for research. They were informed that they would be asked to take part in the management of an obstetric anesthesia crisis, that their role in the scenario would be their current real-life role - a CA-1 resident in the first week of their initial obstetric anesthesia rotation and that A.J.L. would be their supervising attending anesthesiologist. They were oriented to the operating room set-up, the mannequin with an intravenous line established and embedded persons in the scenario (obstetrician and surgical assistant), as well as logistical concerns such as how to draw up simulated medications, where vital signs would be displayed and how to communicate with persons outside of the room (a mock telephone was provided).

The HFS scenario designed starts with the learner being notified verbally by A.J.L. that they have been paged to go emergently to the obstetric operating room. Upon entering the simulated operating room, they are greeted by the obstetric surgeon positioned next to the patient on the operating table, with a vaginally-placed hand elevating the fetal head to relieve pressure on the umbilical cord. The obstetrician hurriedly reports that there is fetal compromise and bradycardia secondary to vaginal prolapse of the umbilical cord and the parturient needs to be immediately anesthetized for emergency cesarean delivery. The embedded persons were instructed to prompt the learner to call for help if they had not done so after about 1 – 1.5 minutes after entering the scene; they were also instructed to report that there was poor uterine tone if the participant had not begun oxytocin administration about 1 – 1.5 minutes after delivery.

Similar to EmergenCSim™, the expected actions for this scenario were adapted from a previously validated 52-item behavior checklist and weighted objective scoring system developed by Scavone et al.[4] described above. The simulation checklist items were rated on an anchored ordinal scale (0 – 2; 0 = “action not done”, 1 = “partially done

or performed, but not timely”, 2 = “correctly done”). The value of the weighted score for each action item was multiplied by the 0, 1 or 2. Therefore, the total achievable score for the simulation was 393.

Development of Knowledge Test

The details of instrument development have been published previously [6].

References:

- [1] S. Deering, L. C. Johnston, and K. Colacchio, "Multidisciplinary teamwork and communication training," (in eng), *Seminars in perinatology*, vol. 35, no. 2, pp. 89-96, Apr 2011, doi: 10.1053/j.semperi.2011.01.009.
- [2] M. Rall and P. Dieckmann, "Safety culture and crisis resource management in airway management: general principles to enhance patient safety in critical airway situations," (in eng), *Best practice & research. Clinical anaesthesiology*, vol. 19, no. 4, pp. 539-57, Dec 2005, doi: 10.1016/j.bpa.2005.07.005.
- [3] P. Dewachter, C. Mouton-Faivre, and D. L. Hepner, "Perioperative anaphylaxis: what should be known?," (in eng), *Curr Allergy Asthma Rep*, vol. 15, no. 5, p. 21, May 2015, doi: 10.1007/s11882-015-0522-4.
- [4] B. M. Scavone *et al.*, "Development of an objective scoring system for measurement of resident performance on the human patient simulator," (in eng), *Anesthesiology*, vol. 105, no. 2, pp. 260-6, Aug 2006.
- [5] J. W. Rudolph, R. Simon, R. L. Dufresne, and D. B. Raemer, "There's no such thing as "nonjudgmental" debriefing: a theory and method for debriefing with good judgment," (in eng), *Simulation in healthcare : journal of the Society for Simulation in Healthcare*, vol. 1, no. 1, pp. 49-55, Spring 2006.
- [6] A. J. Lee, S. R. Goodman, S. E. Banks, M. Lin, and R. Landau, "Development of a Multiple-Choice Test for Novice Anesthesia Residents to Evaluate Knowledge Related to Management of General Anesthesia for Urgent Cesarean Delivery," (in eng), *J Educ Perioper Med*, vol. 20, no. 2, p. E621, Apr-Jun 2018.

Table: Serious game and behavior checklist tasks for the performance of general anesthesia for emergency cesarean delivery and weighted scores (modified from Scavone et al., Ref. 4).

List of Tasks General Anesthesia for Emergency Cesarean Delivery	EmergenCSim™ Weighted Score	Simulation (HFS) Weighted Score	Comment
Preoperative assessment			
Introduce self	3	3	
Obtain pertinent obstetric history	4.5	4.5	
Medical history	4	4	
Medications	4	4	
Allergies	5	5	
Previous anesthetic/family anesthetic history	4	4	
Airway examination	5	5	
Preoperative patient care			
Call attending for help	3	3	New action item
Administer sodium citrate	2	2	Reduced by 2 points from original
Administer 100% oxygen by mask	5	5	
Left uterine displacement	2	2	Reduced by 2 points from original
Ensure working intravenous catheter	5	5	
Apply blood pressure cuff	5	5	
Apply pulse oximeter	5	5	
Apply electrocardiogram leads	3	3	
Equipment availability check*			*Items grouped as a checklist in game
Quick circuit check*	5	5	
Endotracheal tube*	4.5	4.5	
Syringe*	4	4	
Stylet*	4	4	
Laryngoscope with functional light*	5	5	
Functional suction*	5	5	
Prepare medications*	2	2	New action item
Induction/intubation			
Pulse oximeter audible	5	5	
Blood pressure monitor cycling	3	3	
Electrocardiogram functioning	3	3	

Verify obstetric team readiness	5	5	
Administer induction agent #	5	5	#-Game - grouped as drag/drop menu items
Administer succinylcholine #	5	5	
Wait for medication effect	5	5	
Apply cricoid pressure #	5	5	
Direct laryngoscopy #	5	5	
Pass endotracheal tube #	5	5	
Inflate cuff #	5	5	
Confirm presence of end-tidal carbon dioxide #	5	5	
Release cricoid pressure #	3.5	3.5	
Notify obstetrician to proceed	5	5	
Confirm bilateral breath sounds	4	4	
Secure endotracheal tube	3.5	3.5	
Intraoperative management			
Before delivery:			
Initiate mechanical ventilation	5	5	
Appropriate tidal volume/respiratory rate	3	3	
Maintain $\text{FiO}_2 \geq 0.5$	4	4	
Maintain inhaled agent ≥ 1 MAC	3.5	3.5	
Protect eyes	3.5	3.5	
Orogastric tube placed and suctioned	2	2	
Temperature monitored	2	2	
Peripheral nerve simulator placed	2.5	2.5	
After delivery:			
Begin oxytocin infusion	4	4	HFS-if not started: actor reports uterine atony
Decrease inhaled agent < 0.5 MAC	3	3	
Administer nitrous oxide	3	3	
Administer opioid as needed	0	0	HFS-if not given, tachycardia/hypertension
Administer hypnotic as needed	0	0	
Administer muscle relaxant as needed	0	0	

HFS = high-fidelity simulation