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21

1 **ABSTRACT.**

2 Background

3 Low-fidelity simulations are cost-effective, accessible tools for medical education. This study describes the
4 development and initial implementation of a low-cost, easy-to-run simulation, assesses participant performance
5 in airway management and ACLS, and reviews qualitative feedback to refine future iterations.

6

7 Methods

8 This single-center, prospective observational study piloted a low-fidelity simulation on difficult airway
9 management and intraoperative cardiac arrest for fourth-year medical students in a three-hour workshop.
10 Participant demographics, simulation performance, and post-simulation feedback were analyzed using
11 proportions and Fisher's exact test.

12

13 Results

14 A total of eleven medical students participated in the simulation, with most participants scoring in the higher
15 range. No statistically significant findings using the Fisher's exact test were detected between student
16 performance and past experiences in related fields of anesthesiology, critical care medicine, or emergency
17 medicine. Learners had the most difficulty with adherence to ACLS pathways when managing a simulated
18 cardiac arrest, scoring on average 4.5 ± 1.6 points out of 8. Six of the eleven participants completed the post-
19 simulation survey (55% response rate), primarily giving positive feedback, with all responses indicating
20 agreement that low-fidelity simulations are beneficial learning opportunities for medical students, citing them as
21 helpful to review knowledge.

22

23 Conclusion

24 Low-fidelity simulations provide an underutilized yet effective means for skill development in medical education.
25 ACLS performance gaps may stem from limited practice or situational stress. This simulation requires minimal
26 resources and personnel, making it easily adoptable. Future improvements include a larger sample size, clearer
27 questions, and preparatory materials.

28

29 **Key Words:** Medical education, anesthesiology, patient simulation, medical students (Source: MeSH-NLM).

30

1 INTRODUCTION.

2
3 The use of clinical simulations to hone routine skills in a safe environment and practice for rare events
4 is ubiquitous across many medical specialties, especially anesthesiology.¹ A large body of literature exists on
5 simulations in anesthesiology, with most of these activities indicated for resident training.²⁻⁶ Anesthesiologists
6 regularly encounter high-risk scenarios that can be rehearsed using simulation to minimize the potential for
7 patient harm.⁷ Within teaching hospitals, it is feasible to consider extending the participants of these simulations
8 to medical students entering anesthesiology and related fields of critical care medicine and emergency
9 medicine.⁸ Several recent anesthesiology simulations that include medical students have stressed a need for
10 continued research and development of these educational activities for this audience.⁹⁻¹³

11 According to a 2014 survey by the Association of American Medical Colleges (AAMC), nearly all medical
12 schools accredited by the Liaison Committee on Medical Education (LCME) reported having a physical
13 simulation center.¹⁴ Yet, although the infrastructure is present, the use of simulation in medical school is limited
14 by real-world factors such as time, faculty or staff availability for running simulations, and operating costs.^{15,16}
15 Technologically sophisticated, expensive, high-fidelity simulations are often touted as the best instructive
16 experience, but Massoth et al. found that medical students randomized to one such high-fidelity simulation did
17 not outperform their peers assigned to a low-fidelity simulation focusing on Advanced Cardiovascular Life
18 Support (ACLS) and were even noted to overestimate their abilities.¹⁷ In other literature, a low-fidelity
19 "CardioSim" that employed role play between third- and fourth-year medical students noted that all participants
20 had improved confidence in the management of myocardial infarctions after the activity.¹⁸ Similarly, 75% of
21 fourth-year medical students who took a two-week residency preparation course voted "agree" or "strongly
22 agree" to the value of a virtual, low-fidelity critical care simulator; likewise, nearly 80% felt the activity helped
23 apply and reinforce textbook knowledge.¹⁹ Thus, low-fidelity simulations could be considered nearly equivalent
24 and may be more accessible to institutions that either lack adequate simulation spaces or are located in
25 resource-scarce settings.²⁰

26 Based on this review of the literature, it is hypothesized that low-fidelity simulations are an effective tool
27 for teaching critical concepts in anesthesiology to medical students. The objective of this project is to describe
28 the development and initial use of a low-fidelity, minimal-cost, easy-to-run simulation that was designed to
29 prepare graduating fourth-year medical students for the start of internship. Specific goals of this preliminary
30 trial were to analyze participant performance on key principles of airway management and ACLS as well as
31 review qualitative feedback that will help guide future iterations of this educational tool.
32

1 METHODS.

2
3 This single center, prospective observational study was performed at The Warren Alpert Medical
4 School of Brown University with fourth-year medical students who voluntarily enrolled in the clinical elective
5 “IPC 4318: Common Topics in Anesthesia,” a one-time, three-hour workshop held on February 7, 2024 within
6 the institution’s “internship preparation courses.” Subjects covered include advanced airway management
7 techniques such as fiberoptic intubation; intravenous (IV) and central line access techniques; basic point-of-
8 care ultrasound (POCUS) examinations including cardiac, lung and gastric; as well as common regional
9 anesthesia nerve blocks. The low-fidelity simulation was included as one of several stations that students
10 rotated through.

11 Simulation Development

12
13 The simulation was developed using references from The Open Critical Care Project with a focus on
14 difficult airway management and intraoperative cardiac arrest resuscitation tailored to the expected knowledge
15 of a medical student.²¹ These topics were selected because of their applicability to general anesthesiology
16 practice as well as their alignment with Accreditation Council for Graduate Medical Education (ACGME) minimal
17 residency practice requirements. Primary learning objectives for the simulation (Table 1) were adapted from
18 Levels 1-2 of the Anesthesiology Milestones from the ACGME; because this simulation does not include hands-
19 on practice, these objectives are for cognitive domains only.²² By the end of the simulation, the goal was to
20 have students attempt to perform the following: basic preoperative chart review; anesthetic planning;
21 identification and live interpretation of American Society of Anesthesiologists (ASA) standard monitoring criteria
22 to inform next steps in patient care; and management of expected and unexpected events during anesthetic
23 care following the ASA Practice Guidelines for Management of the Difficult Airway²³ as well as the American
24 Heart Association (AHA) ACLS Adult Cardiac Arrest Algorithm.²⁴ No specific preparation materials were
25 required for learners; however, familiarity with these guidelines could improve performance. Inclusion criteria
26 consisted of enrollment in the course; there were no prespecified exclusion criteria.

27 Simulation Execution

28
29 The overarching flow of the simulation occurs over three parts, which are anesthesia induction, airway
30 management, and intraoperative cardiac arrest (Table 2, Supplements 1 and 2). Throughout the entire
31 experience, the medical student learner acts as an attending anesthesiologist supervising a trainee. Briefly,
32 each part includes several questions for the student to answer regarding the simulated anesthetic case along
33 with live interpretation of vital signs presented on an iPad running a mock anesthesia monitor app, SimMon
34 (Castle+Andersen ApS; Copenhagen, Denmark). Using both narrative information and vital signs data, the
35 student essentially reasons through their management of a patient undergoing a common surgery that develops
36 several complications. As the case progresses and the patient’s vital signs become increasingly unstable until
37 the point of cardiac arrest, the student must recognize this acute change and plan their next steps. Importantly,
38 this simulation is designed to continue as written even if the questions are answered incorrectly—there are no
39 discrete branch points. If the learner does not answer all components of a multipart question, partial credit may
40 only be awarded if this is stated in the facilitator guide. Otherwise, the question is marked as wrong, and the
41 simulation continues. All scoring was completed by one researcher to avoid any possible inter-rater differences

1 in this pilot study. Furthermore, the researcher achieved consistency in scoring by continually referencing the
2 answer key's guidelines for half or full credit and did not deviate from these stipulations.

3 4 Simulation Scoring and Analysis

5 Prior to initiating the simulation, all participants completed an anonymous, written, multiple-choice basic
6 demographics form that also included what medical specialty they were applying into (Supplement 3). After the
7 workshop concluded, an online, anonymous post-simulation survey created using Qualtrics was distributed to
8 students via their school email accounts (Supplement 4). The survey was developed referencing similar post-
9 simulation evaluation tools published in the literature.^{4,5} Questions focused on students' perceptions of the
10 simulation experience and their opinions on low-fidelity simulations in general. To compare opinions on the
11 airway management versus the intraoperative cardiac arrest portions of the simulation, two identical blocks of
12 questions were presented. Scoring utilized a Likert scale from 1-5 (1 = Strongly Disagree, 2 = Disagree, 3 =
13 Neutral, 4 = Agree, and 5 = Strongly Agree). Two questions required a "Yes" or "No" answer followed by the
14 ability to elaborate on their choice. Survey participants were also presented with an optional chance to provide
15 comments on the entire simulation experience.

16 All analyses were performed using Stata/SE 17.0, StataCorp LLC. Numerical student scores were
17 categorized as "low" (0 to 7.5 points, inclusively) or "high" (8 to 15 points, inclusively) to perform comparisons
18 with other categorical variables using the Fisher's exact test given the small sample size. Statistical significance
19 was set at $p < 0.05$ with a concurrent understanding of the limitations of p -value analyses when drawing
20 conclusions. Qualitative feedback was divided into the groupings of positive, neutral, or negative comments
21 depending on the text content to form proportions. For questions that utilized a 5-point Likert scale, means and
22 standard deviations were generated to note overall trends. All authors attest to the accuracy of the data and
23 fidelity of statistical analyses. This study was declared as curriculum review, not requiring formal informed
24 consent of participants, and consequently exempt from the Brown University Institutional Review Board. This
25 determination has been made according to the definition of research provided in Title 45 CFR Part 46.102(l).

1 RESULTS.

2
3 In this pilot study, a total of eleven fourth-year medical students enrolled in IPC 4318 and completed
4 the simulation activity. Basic demographics and intended medical specialty reported from the pre-simulation
5 questionnaire are described in Table 3. Participants consisted of seven male-identifying and four female-
6 identifying students, with all but one applying to a single specialty. Most students were white/Caucasian and
7 non-Hispanic/Latino or Spanish origin. Approximately half of the group desired to practice in a non-surgical
8 specialty, which consisted of psychiatry, anesthesiology, emergency medicine, and internal medicine.
9 Represented surgical fields included OB/GYN, otolaryngology, neurosurgery, plastic surgery, and general
10 surgery. Simulation scores had a mean \pm standard deviation of 9.3 ± 2.3 points with a median of 9 and mode
11 of 10.5; the range was from a low of 6 points to a high of 14 (Table 4). Regarding subsection performance, it
12 can be observed that the lowest scoring portion was the third part on intraoperative cardiac arrest; on average,
13 participants scored about 4.5 ± 1.6 points out of 8. The opening scenario and initial questions resulted in middle-
14 range scores, approximately 3 ± 1.2 points out of 5. Learners generally scored close to full credit in the second
15 section with 1.7 ± 0.6 points, which had two questions on airway management and a maximum score of 2. A
16 breakdown of each question and the proportion of students who answered correctly is described in Table 5.

17 As detailed in Figure 1, participants had a mix of experiences taking electives or subinternships in
18 anesthesiology, ICU/critical care medicine, or emergency medicine. The initial demographics survey inquired
19 about shadowing experience in each respective field, as well as enrollment in the anesthesiology pre-clinical
20 elective offered at The Warren Alpert Medical School, but due to the small sample size and lack of positive
21 responses to those questions, the focus was shifted to enrollment in clinical electives only. Some students had
22 experiences in two categories, but no single person had experiences in all three.

23 Most students achieved simulation scores in the high category; of this group, the average score was
24 10.3 ± 1.9 points. Within the low category, the average score was 6.7 ± 0.8 points, and it can be noted that
25 poor performance in the cardiac arrest section primarily drove their score classification. Due to the small sample
26 size, a one-sided Fisher's exact test was performed to assess any meaningful relationship between score
27 category and experience in anesthesiology, ICU/critical care medicine, or emergency medicine. All three tests
28 did not lead to statistically significant *p*-values.

29 Six of the eleven students that participated in the simulation completed the optional, anonymous,
30 emailed online post-simulation survey, a 55% response rate. Summary data regarding perception of the
31 simulation and its content is presented in Table 6. In general, participants provided positive feedback on the
32 simulation, with all responses indicating agreement with a statement on low-fidelity simulations being beneficial
33 learning opportunities for medical students, citing them as helpful to review knowledge. Of the six responses,
34 five agreed with the proposed idea that all medical students should be required to participate in low-fidelity
35 simulations as part of their school's clinical curriculum. Regarding this proposal, one respondent commented,
36 "Ward time constitutes a fair amount of wasted time, and classroom knowledge isn't readily applicable without
37 applying it to at least a few simulations throughout training."

38 Viewing Likert scale data, responses to general statements such as "The simulation was a valuable
39 learning experience," and "The simulation was applicable to my upcoming responsibilities as an intern,"
40 averaged 4 ± 0.9 points and 4.3 ± 1 points respectively, which correspond to "Agree." When asked if "The
41 simulation felt realistic," and "I felt it was fine that the simulation was not hands-on," responses tended to

1 aggregate around 3.5 ± 1.4 and 3.5 ± 0.5 points correspondingly, equaling “Neutral” to “Agree” on the Likert
2 scale. Duplicate question sets were presented for the airway management and the intraoperative cardiac arrest
3 portions of the simulation to compare answers. Both blocks had mean Likert scores ranging from 4 to 4.7, with
4 no obvious differences in responses for each section. Of note, the cardiac arrest portion was apparently more
5 stressful (4 ± 1.3) than the difficult airway portion (4.5 ± 0.5); differences in mean scores indicate less agreement
6 with the statement, “This portion was not overly stressful.” The lowest average Likert scores for these question
7 blocks was regarding the statement, “This portion enhanced my confidence and clinical decision-making skills
8 for the future,” where the difficult airway was 3.8 ± 1.3 points and the cardiac arrest was 3.5 ± 1.2 points, primarily
9 clustering in the “Neutral” to “Agree” categories.
10

Accepted, in-press

1 DISCUSSION.

2
3 This study describes the initial use of a low-fidelity simulation for fourth-year medical students that
4 focuses on the steps one would take to manage both a difficult airway and cardiac arrest while in the operating
5 room. Additionally, specific goals of this pilot test were to analyze participant performance and review qualitative
6 feedback to guide future iterations of this educational tool. In the post-simulation follow-up survey, participants
7 generally provided positive observations on the experience and felt the simulation was a good refresher on
8 airway management and ACLS. A unique component of this simulation is the live interpretation of data from a
9 simulated anesthesia monitor to inform the participant of the patient's immediate status. Simulations are known
10 to be more challenging than written exams, but offer learners a more lifelike environment to demonstrate their
11 knowledge and abilities while simultaneously presenting rare disease states or situations that may otherwise
12 not be encountered in regular practice.²⁵ With this population consisting of medical students at the cusp of
13 graduation and intern year, this simulation may be considered a readiness assessment and can help identify
14 areas for improvement within the medical school curriculum. Given the comment from one participant
15 mentioning that time on a hospital ward does not guarantee learning opportunities, simulations such as the one
16 used in this study represent efficient teaching tools for students' often busy schedules.

17 Although students generally performed well, as only three (27%) individuals scored in the low range,
18 there are clear opportunities for growth, mainly regarding application of the ACLS Adult Cardiac Arrest
19 Algorithm. As noted in Table 5, two questions proved especially challenging: "How is amiodarone dosed for
20 cardiac arrest?" (one correct answer, 9%) and "Given the patient's advanced airway, how often are they
21 ventilated?" (zero correct answers, 0%). There were also difficulties in realizing asystole is a non-shockable
22 rhythm, with only six (55%) individuals answering the question correctly. However, this contrasts with
23 consistently accurate identification of ventricular tachycardia ("What is this cardiac rhythm?") on the simulated
24 monitor, as only one (9%) student failed to do this at the start of the third section. Other difficult questions
25 included knowing specific drugs and dosages used in cardiac arrest ("What is the dose of epinephrine for cardiac
26 arrest?"; "How is amiodarone dosed for cardiac arrest?"), the use of preoxygenation at the start of an anesthetic
27 ("How should you start the induction?"), and identification of standard intraoperative monitoring devices ("What
28 are the five standard ASA monitoring devices you should use?"). On more than one occasion, learners did not
29 fully address all aspects of in-hospital cardiac arrest care such as administering medications, instead focusing
30 on compressions and rescue breaths.

31 Despite immediately noticing auditory cues and alarms, learners had trouble analyzing the live vital
32 signs data in an efficient manner to determine their next steps in the case. It is likely that medical students are
33 unaccustomed to viewing monitors and forming rapid assessments in their clinical training; instead, they are
34 often given vignettes on tests or in case discussions, pointing out an educational benefit from this type of
35 simulation. Alternatively, the stress of the simulation could have impacted their ability to clearly reason through
36 the case; Anton et al. studied physiological and psychological markers of anxiety and found a negative
37 correlation between higher stress levels and simulation performance.²⁶ A possible improvement for the future
38 would be to provide students with a brief handout or reference on common monitoring devices used in
39 anesthesia and rapid cardiac rhythm recognition so they could best understand the data presented to them and
40 experience less pressure.

1 It is well-established in the literature that medical students seldom have adequate experiences applying
2 ACLS pathways outside of dedicated training courses, which is problematic when they graduate and are
3 expected to serve as a code team leader.^{27,28} Research has pointed to the benefits of high-fidelity simulations²⁵
4 over standard, non-lifelike simulations to improve medical student performance and increase confidence in
5 running codes.²⁹ However, certain metrics within ACLS algorithms such as timing of compressions and
6 defibrillation were comparable between groups in Ko et al., suggesting that some benefits may be conferred
7 even without the use of advanced mannequins and simulation equipment.²⁹ Given the participants tended to
8 have neutral Likert scale ratings for enhancing confidence and clinical decision-making skills, this may be related
9 to previous findings that low-fidelity simulations may not adequately instill self-assurance in learners. As noted
10 by Nacca et al., supplementation of a computer-based low-fidelity simulation within a high-fidelity mannequin-
11 based simulation ACLS course for medical students resulted in quicker, accurate decision-making when
12 compared to the mannequin-only group; yet, once more, the low-fidelity simulation group tended to feel less
13 confident in their actions, even if correct.³⁰ When considering these findings, it appears that low-fidelity
14 simulations may have an important role as adjunctive teaching tools within a comprehensive ACLS course that
15 includes elements of realism.

16 Unlike the cardiac arrest portion, students generally excelled with the difficult airway questions in the
17 simulation. These findings could be explained by the inherent variable steps one may take to manage a difficult
18 airway, such as switching a laryngoscope blade or utilizing a videolaryngoscope versus trying a different airway
19 device, whereas ACLS requires set drug dosing, timing of interventions, and ordered actions. Moreover, with
20 only two questions to answer, students had greater chances of performing well. This portion of the simulation
21 was also highly simplified, with the student not physically attempting to intubate a mannequin, which could lead
22 to increased stress and impaired thinking. Comparable studies have noted that students can achieve higher
23 proficiencies in the setting of uncomplicated instructional pathways, as was the case with Ambardekar et al.,
24 who found that following a simplified difficult airway aid resulted in less cognitive burden and better performance
25 outcomes.³¹ It is also important to highlight that interactive discussions of how to manage a difficult airway,
26 essentially what was done within this simulation, provides benefits to learners; in effect, physical practice is not
27 required to optimize education on this topic.³²

28 Strengths of this simulation are that it does not require an expensive setup, it can be conducted with as
29 few as one facilitator, and on average, it takes no more than 15 minutes to perform. At minimum, it can be
30 carried out with the medical student learner and a primary facilitator, who may be an anesthesia resident or
31 attending. Minimum necessary supplies include the patient scenario (Supplement 1) for the learner, the
32 facilitator guide (Supplement 2) for running and scoring the simulation, and an iPad or comparable device (e.g.,
33 smartphone) controlled by the primary facilitator to display live vital signs on a simulator app, of which a variety
34 of paid and free options are available. Specific dialogue is included in the simulation to maintain consistency
35 across repeat trials; no additional dialogue or questions outside of the written case should be stated.

36 Ideally, a secondary facilitator, either an anesthesia resident or attending, can be present to act as an
37 anesthesia provider that can perform the tasks to make the simulation more engaging, if this is done, additional
38 equipment includes a mannequin that can be intubated, standard airway equipment (e.g., adult facemask, oral
39 airway, endotracheal tube, laryngeal mask airway, laryngoscope with Mac and Miller blades, Ambu bag,
40 bougie), mock medications, and a mock defibrillator with pads. Essentially, the primary facilitator will be running
41 the case and asking questions while the secondary facilitator will provide periodic updates on the situation as it

1 is acted out. Having a third facilitator would allow for distribution of the primary facilitator's responsibilities, such
2 as a dedicated person to operate the iPad. This pilot study was conducted using two facilitators for one medical
3 student learner, reflected here in the methods, Table 2, and in the facilitator guide. Additionally, the role of the
4 anesthesia trainee does not need to exclusively be clinical anesthesia year 1 resident (CA-1) as it is written in
5 the materials.

6 Some limitations to this study include the small sample size, which greatly limited abilities to detect
7 significant associations with the Fisher's exact test, potentially masking true relationships between variables. If
8 this simulation were to be repeated with a larger group of students, experiences in critical-care related fields
9 and scoring trends could be explored with correlation analyses. With medical students having earlier exposure
10 to anesthesiology through preclinical electives, it is feasible that a moderate number of individuals could have
11 familiarity with the subjects covered in this simulation as they near graduation, bringing into question possible
12 self-selection bias for individuals already primed to perform well.³³ This was also the first-time use of this
13 simulation, which led to unforeseen challenges related to defining unclear terminology and answering learners'
14 clarifying questions. Scoring accuracy may also be increased by providing more partial credit for questions,
15 especially those that require multiple responses, such as identifying the five standard ASA monitoring devices.
16 A large proportion of students could identify three or four, but since they did not name all five, no credit was
17 awarded. Future iterations could give a half point if at least three devices are correctly named. Lastly, as this
18 study was conducted at a single center, this particular student population could risk not being representative of
19 all medical students in the United States.

Accepted, in press

1 **CONCLUSION.**

2

3 Low-fidelity simulations represent an underutilized tool in medical education that can provide learners
4 with an effective experience to practice skills and demonstrate knowledge. This preliminary trial of one such
5 simulation focusing on a challenging intubation leading to intraoperative cardiac arrest for fourth-year medical
6 students was generally well-received, with most participants earning higher-range scores. Of note, learners
7 found the subsection on ACLS to be the most challenging as it had the lowest mean total scores and was
8 reported to be the most subjectively stressful portion of the simulation. Whether these results were due to lack
9 of practice or stress remains an area for forthcoming investigation. This simulation can be run with limited
10 supplies and personnel in under 15 minutes per trial, allowing easy adoption and use at peer institutions. Future
11 trials of this simulation include obtaining a larger sample size, improving the clarity of questions, and providing
12 preparatory reading material to refresh participants' knowledge on the tested topics.

13

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1 **SUMMARY - ACCELERATING TRANSLATION**

2 Title: Preliminary Trial of a Low-Fidelity Anesthesiology Simulation on Airway Management and Intraoperative
3 Cardiac Arrest for Fourth-Year Medical Students

4 Simulations in healthcare are valuable learning opportunities and are used across many medical
5 specialties, including anesthesiology. Low-fidelity simulations are inexpensive, accessible, and can be helpful
6 in educating medical students. The objective of this work was to pilot a low-fidelity simulation and evaluate
7 student performance plus opportunities for improvement of this learning tool.

8 This study was completed at one medical school and was designed to prospectively observe fourth-
9 year medical student performance on the simulated patient case. A total of eleven fourth-year medical students
10 participated in the simulation, with the majority scoring well. No relationship between student experience in
11 anesthesiology or related fields and simulation score was noted. Six of the eleven participants completed the
12 post-simulation survey (55% response rate), primarily giving positive feedback, with all responses indicating
13 agreement that low-fidelity simulations are beneficial learning opportunities for medical students, citing them as
14 helpful to review knowledge.

15 Low-fidelity simulations represent an underutilized tool in medical education that can provide learners
16 with an effective experience to practice skills and demonstrate knowledge. This simulation can be run with
17 limited supplies and personnel in under 15 minutes per trial, allowing easy adoption and use at peer institutions.

Accepted, improved

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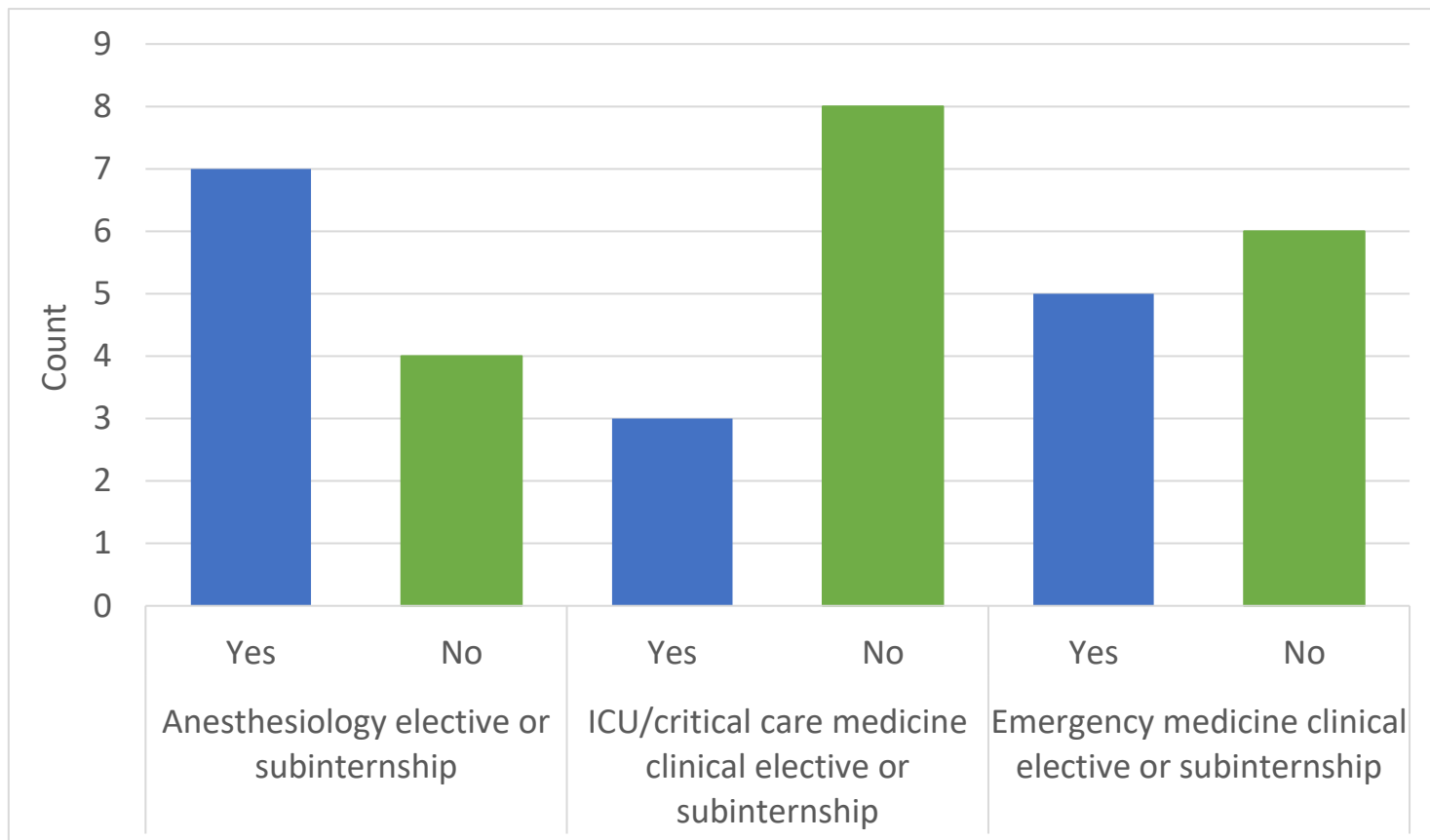
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Accepted, in-press

1 **FIGURES AND TABLES.**

2

3 **Figure 1:** Participant Clinical Experiences Prior to Simulation.



23

24 Legend: ICU, Intensive Care Unit

Accepted

- 1 **Table 1:** Simulation Primary Learning Objectives and Anesthesiology Milestones from the Accreditation Council
2 for Graduate Medical Education (ACGME)

Learning Objective	Residency Milestone
Performs basic chart review	Patient Care 1: Pre-Anesthetic Evaluation, Level 1
Identifies the components of an anesthetic plan and pain management plan	Patient Care 2: Peri-Operative Care and Management, Level 1
Identifies standard monitors and interprets standard monitoring data	Patient Care 3: Application and Interpretation of Monitors, Level 1
Manages expected events during anesthetic care, with supervision	Patient Care 4: Intra-Operative Care, Level 2
Participates in management during crisis situations	Patient Care 7: Situational Awareness and Crisis Management, Level 2
Recognizes when a patient is critically ill	Patient Care 9: Critical Care, Level 1
Demonstrates knowledge of pharmacology of medications routinely used in anesthetic care	Medical Knowledge 1: Foundational Knowledge, Level 2

3

Accepted, in press

1 **Table 2:** General Simulation Flow, Sample Narrative Sections, and Summary of Each Section's Questions. Full
2 text is presented in Supplement 1 and Supplement 2.

3
4

	Narrative	Vital Signs Monitor	Questions
Section 1: Induction	<p>Introduces 45-year-old patient undergoing laparoscopic cholecystectomy with several factors increasing the risk of a difficult airway.</p> <p><i>At section end:</i> The case proceeds with simulated induction and an attempt to intubate with an endotracheal tube.</p>	<ul style="list-style-type: none"> • HR 85 [normal sinus rhythm] • SpO₂ 100% on room air • BP 130/88 • RR 14 	Anesthesia concerns, identification of monitoring devices, process of inducing general anesthesia.
Section 2: Airway Management	<p>There are difficulties in securing an airway for this patient.</p> <p><i>At section end:</i> After multiple tries, the patient is successfully intubated.</p>	<ul style="list-style-type: none"> • HR 120 [sinus tachycardia] • SpO₂ 85% on room air • BP 90/60 • RR 0 	Basic reasoning though a difficult airway, how to recognize unintentional esophageal intubation.
Section 3: Intraoperative Cardiac Arrest	<p>The patient's pulse is suddenly lost.</p>	<ul style="list-style-type: none"> • HR 160 bpm [ventricular tachycardia] • SpO₂ 76%, intubated, 100% FiO₂ • BP 60/40 • RR 0 	Live cardiac rhythm interpretation, key steps in the ACLS Adult Cardiac Arrest Algorithm, medication options, reversible causes of cardiac arrest.
Wrap-Up	<p>Return of spontaneous circulation is achieved and the operation is cancelled. The patient is transferred to the ICU with stable vital signs.</p> <p>Calculate the learner's score, then debrief the simulation. Review answers and offer an opportunity to ask any questions.</p>		

5

6 Legend: HR, heart rate; SpO₂, oxygen saturation; BP, blood pressure; RR, respiratory rate; ACLS, Advanced
7 Cardiovascular Life Support.

- 1 **Table 3:** Participant Demographics and Specialty Selection. All categories use $n = 11$ except as where noted.
- 2 Data are presented as counts and percentages. Total percentages may not equal 100% due to rounding.

		<i>n</i>	%
Gender Identity	Male	7	64%
	Female	4	36%
Age Category	24 to 26 years	3	27%
	27 to 29 years	3	27%
	30 to 32 years	2	18%
	33 years or older	3	27%
Race	Black/African American	1	9%
	White/Caucasian	9	82%
	Other	1	9%
Ethnicity	Hispanic/Latino or Spanish origin	1	9%
	Not Hispanic/Latino or Spanish origin	10	91%
Intended Specialty* (<i>n</i> = 12)	Anesthesiology	1	8%
	Emergency Medicine	2	17%
	General Surgery	1	8%
	Internal Medicine	2	17%
	Neurosurgery	1	8%
	OB/GYN	2	17%
	Otolaryngology	1	8%
	Plastic Surgery	1	8%
	Psychiatry	1	8%
*One participant applied to both internal medicine and emergency medicine			

- 3
- 4

- 1 **Table 4:** Participant Clinical Experiences and Simulation Scores. Score categories were defined as low if
 2 participants scored from 0 to 7.5 inclusive and high if participants scored from 8 to 15 inclusive.
 3

Participant Number	Section 1 Score (Maximum 5)	Section 2 Score (Maximum 2)	Section 3 Score (Maximum 8)	Total Score (Maximum 15)	Score Category
1	1.5	2	2.5	6	Low
2	2.5	0	4	6.5	Low
3	3.5	2	2	7.5	Low
4	5	2	7	14	High
5	1.5	2	5.5	9	High
6	4	1.5	5	10.5	High
7	2	2	4	8	High
8	3	2	6	11	High
9	4	2	5	11	High
10	4	1.5	3	8.5	High
11	2.5	2	6	10.5	High
Mean Score ± SD	3 ± 1.2	1.7 ± 0.6	4.5 ± 1.6	9.3 ± 2.3	

- 4
 5 Legend: SD, Standard Deviation

- 1 **Table 5:** Aggregated Participant Responses by Question. Full Credit = 1 point; Partial Credit = 0.5 points; No
- 2 Credit = 0 points for scoring purposes. Data are presented as counts and percentages out of a total of 11
- 3 participants. Total percentages may not equal 100% due to rounding.

	Question	Full Credit (n, %)	Partial Credit (n, %)	No Credit (n, %)
Section 1: Induction	Based on the patient's chart, are there any concerns you have about this anesthetic? If so, name at least one factor.	9 (82%)	0 (0%)	2 (18%)
	What are the five standard ASA monitoring devices you should use?	1 (9%)	0 (0%)	10 (91%)
	How should you start the induction?	5 (45%)	0 (0%)	6 (55%)
	Name at least two medications that may be used during induction and briefly describe each's basic mechanism of action.	6 (55%)	4 (36%)	1 (9%)
	Which airway device should you pick?	9 (82%)	1 (9%)	1 (9%)
Section 2: Airway Management	How would you like to proceed? Besides direct laryngoscopy, name at least one other option to use with a suspected difficult airway?	11 (100%)	0 (0%)	0 (0%)
	Name at least two signs that you would expect if the esophagus was intubated by mistake.	8 (73%)	2 (18%)	1 (9%)
Section 3: Intraoperative Cardiac Arrest	What is this cardiac rhythm?	9 (82%)	0 (0%)	2 (18%)
	What is your first step in managing this acute change?	9 (82%)	0 (0%)	2 (18%)
	What are your next steps?	11 (100%)	0 (0%)	0 (0%)
	What is the dose of epinephrine for cardiac arrest?	7 (64%)	0 (0%)	4 (36%)
	How is amiodarone dosed for cardiac arrest?	1 (9%)	0 (0%)	10 (91%)
	Name at least two causes of reversible cardiac arrest.	6 (55%)	2 (18%)	3 (27%)
	Given the patient's advanced airway, how often are they ventilated?	0 (0%)	0 (0%)	11 (100%)
	If the patient's rhythm were to change to asystole, what is the main difference to your management?	6 (55%)	0 (0%)	5 (45%)

4

- 5 Legend: ASA, American Society of Anesthesiologists

1 **Table 6:** Participant Post-Simulation Survey Results. Data are presented as counts and percentages for the
 2 feedback columns. Total percentages may not equal 100% due to rounding. Scoring utilized a Likert scale
 3 from 1-5 (1 = Strongly Disagree, 2 = Disagree, 3 = Neutral, 4 = Agree, and 5 = Strongly Agree). “Positive
 4 Feedback” includes both Strongly Agree and Agree; “Negative Feedback” includes both Disagree and Strongly
 5 Disagree.

	Question Stem	Positive Feedback	Neutral Feedback	Negative Feedback	Mean ± SD Likert Scale Scores
Overall Simulation Experience	The simulation was a valuable learning experience.	4 (67%)	2 (33%)	0 (0%)	4 ± 0.9
	The simulation was at an appropriate level of difficulty.	5 (83%)	1 (17%)	0 (0%)	4.5 ± 0.8
	The simulation was at an appropriate level of stress.	6 (100%)	0 (0%)	0 (0%)	4.7 ± 0.5
	I found the material included in the simulation interesting.	5 (83%)	1 (17%)	0 (0%)	4.3 ± 0.8
	The simulation was applicable to my upcoming responsibilities as an intern.	4 (67%)	2 (33%)	0 (0%)	4.3 ± 1
	This simulation enhanced my confidence and clinical decision-making skills for the future.	3 (50%)	2 (33%)	1 (17%)	3.8 ± 1.3
	The simulation felt realistic.	4 (67%)	1 (17%)	2 (33%)	3.5 ± 1.4
	I felt it was fine that the simulation was not hands-on (e.g., not intubating the mannequin myself).	3 (50%)	3 (50%)	0 (0%)	3.5 ± 0.5
Part 2: Airway Management	I had adequate preparation through my coursework or rotations to answer the questions.	4 (67%)	2 (33%)	0 (0%)	4.3 ± 1
	This portion was at an appropriate level of difficulty.	6 (100%)	0 (0%)	0 (0%)	4.7 ± 0.5
	This portion was not overly stressful.	6 (100%)	0 (0%)	0 (0%)	4.5 ± 0.5
	This portion was applicable to my upcoming responsibilities as an intern.	4 (67%)	2 (33%)	0 (0%)	4.2 ± 1
	This portion enhanced my confidence and clinical decision-making skills for the future.	3 (50%)	2 (33%)	1 (17%)	3.8 ± 1.3
Section 3: Intraoperative Cardiac Arrest	I had adequate preparation through my coursework or rotations to answer the questions.	5 (83%)	0 (0%)	1 (17%)	4.2 ± 1.2
	This portion was at an appropriate level of difficulty.	6 (100%)	0 (0%)	0 (0%)	4.5 ± 0.5
	This portion was not overly stressful.	4 (67%)	1 (17%)	1 (17%)	4 ± 1.3
	This portion was applicable to my upcoming responsibilities as an intern.	5 (83%)	1 (17%)	0 (0%)	4.5 ± 0.8
	This portion enhanced my confidence and clinical decision-making skills for the future.	2 (33%)	3 (50%)	1 (17%)	3.5 ± 1.2

6

7

1 **Supplementary Material 1**

2

3 **Simulation Scenario (Student Version)**

4

5 You are ready to start the anesthesia induction for a case of a 45-year-old male named Gerald Anderson with
6 past medical history of gout, type 2 diabetes mellitus, hypertension, and obesity (BMI 40) who is about to
7 undergo laparoscopic cholecystectomy for acute cholecystitis. His medications include allopurinol, metformin,
8 and irbesartan; he has no allergies; social history is notable for smoking a half pack of cigarettes per day along
9 with recreational cannabis on the weekends.

10

11 His physical exam is notable for a Mallampati 3 airway, limited neck extension, and RUQ tenderness;
12 cardiopulmonary exam reveals lungs CTAB and heart RRR. The patient is in NAD on the operating room table,
13 and you will now assume care of him. Assessment, optimization, and room setup have already been
14 performed—you do not need to repeat these steps.

15

Accepted, in-progress

1 **Supplementary Material 2**

2 **Simulation Scenario (Facilitator Version)**

3 **Section 1: Induction**

4

5 Provide the learner with a copy of the Student Version to review upon initiating the simulation. Vital signs on
6 the monitor are heart rate 85 bpm [normal sinus rhythm]; oxygen saturation 100% on room air; blood pressure
7 130/88 mmHg; and respiratory rate 14 breaths/min. When the learner is ready to begin, ask the following
8 prompts:

9

- 10 1. Based on the patient's chart, are there any concerns you have about this anesthetic? If so, name at
11 least one factor.
- 12 2. What are the five standard ASA monitoring devices you should use?
- 13 3. How should you start the induction?
- 14 4. Name at least two medications that may be used during induction and briefly describe each's basic
15 mechanism of action.
- 16 5. Which airway device should you pick?

17

18 **Section 1 Scoring (1 point each, maximum 5 points)**

- 19 1. Identifies at least one difficult airway risk factor based on the patient's chart. Options include obesity,
20 Mallampati score, or limited neck motion.
- 21 2. Identifies standard ASA monitors: pulse oximeter, EKG, noninvasive blood pressure device,
22 temperature probe, and end-tidal CO₂.
- 23 3. Starts induction with preoxygenation.
- 24 4. At least two of any anxiolytic, hypnotic, paralytic, or analgesic drugs can be identified and each's basic
25 mechanism of action is described. Half-credit may be awarded for identifying medications without
26 knowing the pharmacodynamic activity.
- 27 5. Identifies an appropriate airway device for a general anesthetic case such as an endotracheal tube.

28

29 The case proceeds with simulated induction and an attempt to intubate with an endotracheal tube.

30

31 **Section 1 Score:** _____

32

1 **Section 2: Airway Management**

2

3 The secondary facilitator tells the learner “I am having difficulty visualizing the patient’s airway. There’s also
4 changes on the monitor you should see.” Vital signs on the monitor are heart rate 120 bpm [sinus tachycardia];
5 oxygen saturation 85% on room air; blood pressure 90/60 mmHg; and respiratory rate 0 breaths/min.

6

7 1. How would you like to proceed? Besides direct laryngoscopy, name at least one other option to use
8 with a suspected difficult airway?

9 2. Name at least two signs that you would expect if the esophagus was intubated by mistake.

10

11 **Section 2 Scoring (1 point each, maximum 2 points)**

12

13 1. Options include optimizing positioning; change laryngoscopy blade; utilize a bougie; obtain a
14 videolaryngoscope; perform external laryngeal manipulation; or call for skilled help.

15 2. The learner identifies at least two of the following: no breath sounds on auscultation; absent chest
16 rise/fall with ventilation; no misting or fogging of the endotracheal tube; or no ETCO₂ waveform on
17 monitor.

18

19 The secondary facilitator informs the learner, “It took three tries, but I’ve successfully intubated the patient.”

20

21 **Section 2 Score:** _____

22

23

24

25

Accepted, in press

1 **Section 3: Intraoperative Cardiac Arrest**

2

3 The secondary facilitator tells the learner, "I can't get a pulse on the patient!" Vital signs on the monitor are
4 heart rate 160 [ventricular tachycardia]; oxygen saturation 76% while intubated on 100% FiO₂; blood pressure
5 60/40 mmHg; and respiratory rate 0 breaths/min.

6

7

1. What is this cardiac rhythm?

8

2. What is your first step in managing this acute change?

9

3. What are your next steps?

10

4. What is the dose of epinephrine for cardiac arrest?

11

5. How is amiodarone dosed for cardiac arrest?

12

6. Name at least two causes of reversible cardiac arrest.

13

7. Given the patient's advanced airway, how often are they ventilated?

14

8. If the patient's rhythm were to change to asystole, what is the main difference to your management?

15

16 **Section 3 Scoring (1 point each, maximum 8 points)**

17

1. Identifies the rhythm as pulseless ventricular tachycardia.

18

2. Defibrillates the patient given the shockable rhythm.

19

3. Correctly identifies that CPR will be provided for 2 minutes, followed by rhythm checks for possible repeat defibrillation, along with epinephrine administration every 3-5 minutes. Also, can mention the use of second-line medications such as amiodarone or lidocaine if needed.

20

4. States 1 mg epinephrine.

21

5. States amiodarone boluses are 300 mg for the first dose and 150 mg for the second dose.

22

6. The learner identifies at least two of the following "H's and T's": hypovolemia, hypoxia, hydrogen ion (acidosis), hypo/hyperkalemia, hypothermia, tension pneumothorax, cardiac tamponade, toxins, or pulmonary/coronary thrombosis.

23

7. States one breath every 6 seconds or 10 breaths/minute.

24

8. Identifies that asystole is a non-shockable rhythm.

25

26 **Section 3 Score:** _____

27

28

29

30

31

1 **End of Simulation Wrap-Up**

2

3 **Total Score:** _____

4

5 Return of spontaneous circulation is achieved and the operation is cancelled. The patient is transferred to the
6 ICU with stable vital signs.

7

8 The maximum score for the simulation is 15 points. Calculate the learner's total, then debrief the simulation.

9 Review answers and offer an opportunity to ask any questions.

10

Accepted, in-press

1 **Supplementary Material 3**

2 Sociodemographic questions

3 1. What is your gender identity?

- 4 a. Female
5 b. Male
6 c. Transgender Female
7 d. Transgender Male
8 e. Nonbinary
9 f. Other
10 g. Prefer not to say

11
12 2. What is your age?

- 13 a. Under 18 years
14 b. 18 to 20 years
15 c. 21 to 23 years
16 d. 24 to 26 years
17 e. 27 to 29 years
18 f. 30 to 32 years
19 g. 33 years or older

20
21 3. What is your race?

- 22 a. Asian
23 b. Black/African American
24 c. Native American
25 d. Pacific Islander
26 e. White/Caucasian
27 f. Other (please specify)

28
29 4. What is your ethnicity?

- 30 a. Hispanic/Latino or Spanish origin
31 b. Not Hispanic/Latino or Spanish origin

32
33 5. What medical specialty are you applying into?

- 34 a. Anesthesiology
35 b. Dermatology
36 c. Emergency Medicine
37 d. Family Medicine
38 e. General Surgery
39 f. Internal Medicine
40 g. Medicine-Pediatrics
41 h. Neurology
42 i. OB/GYN
43 j. Pathology
44 k. Pediatrics
45 l. Physical Medicine & Rehabilitation
46 m. Psychiatry
47 n. Radiation Oncology
48 o. Radiology
49 p. Other

50
51 6. For the following statements, please indicate "Yes" if they apply to you or "No" if not:

- 52 a. I have had prior anesthesiology shadowing experience
53 b. I took the anesthesiology pre-clinical elective in my first or second year of medical school
54 c. I have taken an anesthesiology clinical elective (e.g., 2- or 4-week; pediatric anesthesia)
55 d. I have had prior ICU/critical care shadowing experience
56 e. I have taken an ICU/critical care clinical elective or subinternship
57 f. I have had prior emergency medicine shadowing experience
58 g. I have taken an emergency medicine clinical elective or subinternship
59

1 **Supplementary Material 4**

2 Post-Simulation Survey

3
4 Thank you for completing the simulation portion during IPC 4318: Common Topics in Anesthesia. This following
5 survey will anonymously assess students' perceptions of this specific activity ONLY.
6 As a reminder, the simulation scenario focused on inducing general anesthesia for a patient with several risk
7 factors for a difficult airway and asked how to progress through the ASA Difficult Airway algorithm. Due to
8 issues with intubating, the patient suffered an intraoperative cardiac arrest requiring ACLS resuscitation.
9 Please rate your agreement with the following statements regarding the **overall simulation station ONLY**
10 during IPC 4318: Common Topics in Anesthesia.

11 The simulation was a valuable learning experience.

- 13 • Strongly Disagree (1)
- 14 • Disagree (2)
- 15 • Neutral (3)
- 16 • Agree (4)
- 17 • Strongly Agree (5)

18
19 The simulation was at an appropriate level of difficulty.

- 20 • Strongly Disagree (1)
- 21 • Disagree (2)
- 22 • Neutral (3)
- 23 • Agree (4)
- 24 • Strongly Agree (5)

25
26 The simulation was at an appropriate level of stress.

- 27 • Strongly Disagree (1)
- 28 • Disagree (2)
- 29 • Neutral (3)
- 30 • Agree (4)
- 31 • Strongly Agree (5)

32
33 I found the material included in the simulation interesting.

- 34 • Strongly Disagree (1)
- 35 • Disagree (2)
- 36 • Neutral (3)
- 37 • Agree (4)
- 38 • Strongly Agree (5)

39
40 The simulation was applicable to my upcoming responsibilities as an intern.

- 41 • Strongly Disagree (1)
- 42 • Disagree (2)
- 43 • Neutral (3)
- 44 • Agree (4)
- 45 • Strongly Agree (5)

46
47 This simulation enhanced my confidence and clinical decision-making skills for the future.

- 48 • Strongly Disagree (1)
- 49 • Disagree (2)
- 50 • Neutral (3)
- 51 • Agree (4)
- 52 • Strongly Agree (5)

53
54 The simulation felt realistic.

- 55 • Strongly Disagree (1)
- 56 • Disagree (2)
- 57 • Neutral (3)
- 58 • Agree (4)
- 59 • Strongly Agree (5)

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I felt it was fine that the simulation was not hands-on (e.g., not intubating the mannequin myself).

- Strongly Disagree (1)
- Disagree (2)
- Neutral (3)
- Agree (4)
- Strongly Agree (5)

Please rate your agreement with the following statements regarding the **difficult airway portion of the simulation station ONLY** during IPC 4318: Common Topics in Anesthesia.

I had adequate preparation through my coursework or rotations to answer the questions.

- Strongly Disagree (1)
- Disagree (2)
- Neutral (3)
- Agree (4)
- Strongly Agree (5)

This portion was at an appropriate level of difficulty.

- Strongly Disagree (1)
- Disagree (2)
- Neutral (3)
- Agree (4)
- Strongly Agree (5)

This portion was not overly stressful.

- Strongly Disagree (1)
- Disagree (2)
- Neutral (3)
- Agree (4)
- Strongly Agree (5)

This portion was applicable to my upcoming responsibilities as an intern.

- Strongly Disagree (1)
- Disagree (2)
- Neutral (3)
- Agree (4)
- Strongly Agree (5)

This portion enhanced my confidence and clinical decision-making skills for the future.

- Strongly Disagree (1)
- Disagree (2)
- Neutral (3)
- Agree (4)
- Strongly Agree (5)

Please rate your agreement with the following statements regarding the **cardiac arrest / ACLS portion of the simulation station ONLY** during IPC 4318: Common Topics in Anesthesia.

I had adequate preparation through my coursework or rotations to answer the questions.

- Strongly Disagree (1)
- Disagree (2)
- Neutral (3)
- Agree (4)
- Strongly Agree (5)

This portion was at an appropriate level of difficulty.

- Strongly Disagree (1)
- Disagree (2)

- 1 • Neutral (3)
2 • Agree (4)
3 • Strongly Agree (5)
4

5 This portion was not overly stressful.

- 6 • Strongly Disagree (1)
7 • Disagree (2)
8 • Neutral (3)
9 • Agree (4)
10 • Strongly Agree (5)
11

12 This portion was applicable to my upcoming responsibilities as an intern.

- 13 • Strongly Disagree (1)
14 • Disagree (2)
15 • Neutral (3)
16 • Agree (4)
17 • Strongly Agree (5)
18

19 This portion enhanced my confidence and clinical decision-making skills for the future.

- 20 • Strongly Disagree (1)
21 • Disagree (2)
22 • Neutral (3)
23 • Agree (4)
24 • Strongly Agree (5)
25

26 "Low-fidelity simulations" do not utilize the most realistic equipment or closely replicate real-world conditions as
27 compared to "high-fidelity simulations." Given this brief description, do you feel that low-fidelity simulations such
28 as the one piloted in this course are beneficial to student learners? Please indicate Yes or No in the appropriate
29 box and provide any comments as you see fit.

- 30 • Yes Comments:
31 • No Comments:
32

33 Do you believe all medical students should be required to participate in low-fidelity simulations like the one you
34 completed during this course as part of the clinical curriculum? Please indicate Yes or No in the appropriate
35 box and provide any comments as you see fit.

- 36 • Yes Comments:
37 • No Comments:
38

39 Please feel free to add any comments regarding the simulation here: