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Original Article

Evaluating a Low-Fidelity Anesthesiology Simulation for Airway Management and Cardiac Arrest in Medical Students

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Abstract

Background: Low-fidelity simulations are cost-effective, accessible tools for medical education. This study describes the development and initial implementation of a low-cost, easy-to-run simulation, assesses participant performance in airway management and ACLS, and reviews qualitative feedback to refine future iterations. **Methods:** This single-center, prospective observational study piloted a low-fidelity simulation on difficult airway management and intraoperative cardiac arrest for fourth-year medical students in a three-hour workshop. Participant demographics, simulation performance, and post-simulation feedback were analyzed using proportions and Fisher's exact test. **Results:** A total of eleven medical students participated in the simulation, with most participants scoring in the higher range. No statistically significant findings using the Fisher's exact test were detected between student performance and past experiences in related fields of anesthesiology, critical care medicine, or emergency medicine. Learners had the most difficulty with adherence to ACLS pathways when managing a simulated cardiac arrest, scoring on average 4.5 ± 1.6 points out of 8. Six of the eleven participants completed the post-simulation survey (55% response rate), primarily giving positive feedback, with all responses indicating agreement that low-fidelity simulations are beneficial learning opportunities for medical students, citing them as helpful to review knowledge. **Conclusion:** Low-fidelity simulations provide an underutilized yet effective means for skill development in medical education. ACLS performance gaps may stem from limited practice or situational stress. This simulation requires minimal resources and personnel, making it easily adoptable. Future improvements include a larger sample size, clearer questions, and preparatory materials.

Introduction

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

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

Based on this review of the literature, it is hypothesized that low-fidelity simulations are an effective tool for teaching critical

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concepts in anesthesiology to medical students. The objective of this project is to describe the development and initial use of a low-fidelity, minimal-cost, easy-to-run simulation that was designed to prepare graduating fourth-year medical students for the start of internship. Specific goals of this preliminary trial were to analyze participant performance on key principles of airway management and ACLS as well as review qualitative feedback that will help guide future iterations of this educational tool.

Methods

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

Simulation Development

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

Simulation Execution

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

Simulation Scoring and Analysis

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

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

Results

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

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

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

Table 1. Simulation Primary Learning Objectives and Anesthesiology Milestones from the Accreditation Council 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

Table 2. Simulation Flow, Sample Narratives, and Summary of Each Section's Questions. Full text in Supplements 1 and 2.

	Narrative	Vital Signs Monitor	Questions
Section 1: Induction	Introduces 45-year-old patient undergoing laparoscopic cholecystectomy with several factors increasing the risk of a difficult airway. *At section end:* The case proceeds with simulated induction and an attempt to intubate with an endotracheal tube.	• HR 85 [normal sinus rhythm] • SpO_2 100% on room air • BP 130/88 • RR 14	Anesthesia concerns, identification of monitoring devices, process of inducing general anesthesia.
Section 2: Airway Management	There are difficulties in securing an airway for this patient. *At section end:* After multiple tries, the patient is successfully intubated.	• 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	The patient's pulse is suddenly lost.	• 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	Return of spontaneous circulation is achieved and the operation is cancelled. The patient is transferred to the ICU with stable vital signs. Calculate the learner's score, then debrief the simulation. Review answers and offer an opportunity to ask any questions.		

Legend: HR, heart rate; SpO_2, oxygen saturation; BP, blood pressure; RR, respiratory rate; ACLS, Advanced Cardiovascular Life Support.

Figure 1: Participant Clinical Experiences Prior to Simulation.

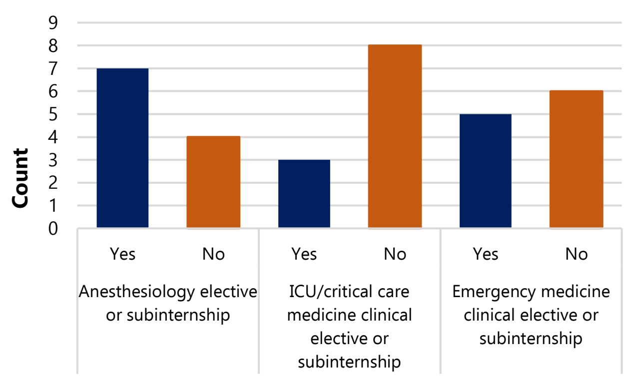

Table 3. Participant Demographics and Specialty Selection.

		n	%
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* (*n* = 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%

Legend: *One participant applied to both internal medicine and emergency medicine. All categories use n = 11 except where noted. Data are presented as counts and percentages. Total percentages may not equal 100% due to rounding.

Table 4. Participant Clinical Experiences and Simulation Scores.

ID	Section 1 score (Max 5)	Section 2 score (Max 2)	Section 3 score (Max 8)	Total Score (Max 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
Score±SD	**3±1.2**	**1.7±0.6**	**4.5±1.6**	**9.3±2.3**	

Legend: SD, Standard Deviation. Score categories were defined as Low for scores from 0 to 7.5 (inclusive) and High for scores from 8 to 15 (inclusive).

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

Viewing Likert scale data, responses to general statements such as "The simulation was a valuable learning experience," and "The simulation was applicable to my upcoming responsibilities as an intern," averaged 4 ± 0.9 points and 4.3 ± 1 points respectively, which correspond to "Agree." When asked if "The simulation felt realistic," and "I felt it was fine that the simulation was not hands-on," responses tended to aggregate around 3.5 ± 1.4 and 3.5 ± 0.5 points correspondingly, equaling "Neutral" to "Agree" on the Likert scale. Duplicate question sets were presented for the airway management and the intraoperative cardiac arrest portions of the simulation to compare answers. Both blocks had mean Likert scores ranging from 4 to 4.7, with no obvious differences in responses for each section. Of note, the cardiac arrest portion was apparently more stressful (4 ± 1.3) than the difficult airway portion (4.5 ± 0.5); differences in mean scores indicate less agreement with the statement, "This portion was not overly stressful." The lowest average Likert scores for these question blocks was regarding the statement, "This portion enhanced my confidence and clinical decision-making skills for the future," where the difficult airway was 3.8 ± 1.3 points and the cardiac arrest was 3.5 ± 1.2 points, primarily clustering in the "Neutral" to "Agree" categories.

Discussion

This study describes the initial use of a low-fidelity simulation for fourth-year medical students that focuses on the steps one would take to manage both a difficult airway and cardiac arrest while in the operating room. Additionally, specific goals of this pilot test were to analyze participant performance and review qualitative feedback to guide future iterations of this educational tool. In the post-simulation follow-up survey, participants generally provided positive observations on the experience and felt the simulation was a good refresher on airway management and ACLS.

A unique component of this simulation is the live interpretation of data from a simulated anesthesia monitor to inform the participant of the patient's immediate status. Simulations are known to be more challenging than written exams, but offer learners a more lifelike environment to demonstrate their knowledge

Table 5. Aggregated Participant Responses by Question.

	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%)

Legend: ASA, American Society of Anesthesiologists. Full credit = 1 point; partial credit = 0.5 points; no credit = 0 points. Data are presented as counts and percentages out of 11 participants. Totals may not equal 100% due to rounding.

Table 6. Aggregated Participant Responses by Question.

	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

Legend: Full credit = 1 point; partial credit = 0.5 points; no credit = 0 points. Data are presented as counts and percentages out of 11 participants. Totals may not equal 100% due to rounding.

and abilities while simultaneously presenting rare disease states or situations that may otherwise not be encountered in regular practice.[25] With this population consisting of medical students at the cusp of graduation and intern year, this simulation may be considered a readiness assessment and can help identify areas for improvement within the medical school curriculum. Given the comment from one participant mentioning that time on a hospital ward does not guarantee learning opportunities, simulations such as the one used in this study represent efficient teaching tools for students' often busy schedules.

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

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

It is well-established in the literature that medical students seldom have adequate experiences applying ACLS pathways outside of dedicated training courses, which is problematic when they graduate and are expected to serve as a code team leader.[27,28] Research has pointed to the benefits of high-fidelity simulations[25] over standard, non-lifelike simulations to improve medical student performance and increase confidence in running codes.[29] However, certain metrics within ACLS algorithms such as timing of compressions and defibrillation were comparable between groups in Ko et al., suggesting that some benefits may be conferred even without the use of advanced mannequins and simulation equipment.[29] Given the participants tended to have neutral Likert scale ratings for enhancing confidence and clinical decision-making skills, this may be related to previous findings that low-fidelity simulations may not adequately instill self-assurance in learners. As noted by Nacca et al., supplementation of a computer-based low-fidelity simulation within a high-fidelity mannequin-based simulation ACLS course for medical students resulted in quicker, accurate decision-making when compared to the mannequin-only group; yet, once more, the low-fidelity simulation group tended to feel less confident in their actions, even if correct.[30] When considering these findings, it appears that low-fidelity simulations may have an important role as adjunctive teaching tools within a comprehensive ACLS course that includes elements of realism.

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

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

Ideally, a secondary facilitator, either an anesthesia resident or attending, can be present to act as an anesthesia provider that can perform the tasks to make the simulation more engaging, if this is done, additional equipment includes a mannequin that can be intubated, standard airway equipment (e.g., adult facemask, oral airway, endotracheal tube, laryngeal mask airway, laryngoscope with Mac and Miller blades, Ambu bag, bougie), mock medications, and a mock defibrillator with pads. Essentially, the primary facilitator will be running the case and asking questions while the secondary facilitator will provide periodic updates on the situation as it is acted out. Having a third facilitator would allow for distribution of the primary facilitator's responsibilities, such as a dedicated person to operate the iPad. This pilot study was conducted using two facilitators for one medical student learner, reflected here in the methods *(Table 2),* and in the facilitator guide. Additionally, the role of the anesthesia trainee does not need to exclusively be clinical anesthesia year 1 resident (CA-1) as it is written in the materials.

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

Conclusion

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

Summary – Accelerating Translation

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

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

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

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

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Author Contributions

Conceptualization: KW, SA. Data Curation: KW, CS, SA. Formal Analysis: KW, SA. Investigation: KW, CS, SA. Methodology: KW, SA. Supervision: SA. Validation: KW, CS, SA. Visualization: KW, CS, SA. Writing - Original Draft: KW. Writing - Review Editing: KW, CS, SA.

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Supplementary Material

Supplementary Material 1

Simulation Scenario (Student Version)

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

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

Supplementary Material 2

Simulation Scenario (Facilitator Version)

Section 1: Induction

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

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

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

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

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

Section 1 Score: _____

Section 2: Airway Management

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

1. How would you like to proceed? Besides direct laryngoscopy, name at least one other option to use with a suspected difficult airway?
2. Name at least two signs that you would expect if the esophagus was intubated by mistake.

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

1. Options include optimizing positioning; change laryngoscopy blade; utilize a bougie; obtain a videolaryngoscope; perform external laryngeal manipulation; or call for skilled help.
2. The learner identifies at least two of the following: no breath sounds on auscultation; absent chest rise/fall with ventilation; no misting or fogging of the endotracheal tube; or no ETCO2 waveform on monitor.

The secondary facilitator informs the learner, "It took three tries, but I've successfully intubated the patient."

Section 2 Score: _____

Section 3: Intraoperative Cardiac Arrest

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

1. What is this cardiac rhythm?
2. What is your first step in managing this acute change?
3. What are your next steps?
4. What is the dose of epinephrine for cardiac arrest?
5. How is amiodarone dosed for cardiac arrest?
6. Name at least two causes of reversible cardiac arrest.
7. Given the patient's advanced airway, how often are they ventilated?
8. If the patient's rhythm were to change to asystole, what is the main difference to your management?

Section 3 Scoring (1 point each, maximum 8 points)
1. Identifies the rhythm as pulseless ventricular tachycardia.
2. Defibrillates the patient given the shockable rhythm.
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.
4. States 1 mg epinephrine.
5. States amiodarone boluses are 300 mg for the first dose and 150 mg for the second dose.
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.
7. States one breath every 6 seconds or 10 breaths/minute.
8. Identifies that asystole is a non-shockable rhythm.

Section 3 Score: _____

End of Simulation Wrap-Up

Total Score: _____

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

The maximum score for the simulation is 15 points. Calculate the learner's total, then debrief the simulation. Review answers and offer an opportunity to ask any questions

Supplementary Material 3

Sociodemographic questions

1. What is your gender identity?
a. Female
b. Male
c. Transgender Female
d. Transgender Male
e. Nonbinary
f. Other
g. Prefer not to say

2. What is your age?

a. Under 18 years
b. 18 to 20 years
c. 21 to 23 years
d. 24 to 26 years
e. 27 to 29 years
f. 30 to 32 years
g. 33 years or older

3. What is your race?
a. Asian
b. Black/African American
c. Native American
d. Pacific Islander
e. White/Caucasian
f. Other (please specify)

4. What is your ethnicity?
a. Hispanic/Latino or Spanish origin
b. Not Hispanic/Latino or Spanish origin

5. What medical specialty are you applying into?
a. Anesthesiology
b. Dermatology
c. Emergency Medicine
d. Family Medicine
e. General Surgery
f. Internal Medicine
g. Medicine-Pediatrics
h. Neurology
i. OB/GYN
j. Pathology
k. Pediatrics
l. Physical Medicine & Rehabilitation
m. Psychiatry
n. Radiation Oncology
o. Radiology
p. Other

6. For the following statements, please indicate "Yes" if they apply to you or "No" if not:
a. I have had prior anesthesiology shadowing experience
b. I took the anesthesiology pre-clinical elective in my first or second year of medical school
c. I have taken an anesthesiology clinical elective (e.g., 2- or 4-week; pediatric anesthesia)
d. I have had prior ICU/critical care shadowing experience
e. I have taken an ICU/critical care clinical elective or subinternship
f. I have had prior emergency medicine shadowing experience
g. I have taken an emergency medicine clinical elective or subinternship

Supplementary Material 4

Post-Simulation Survey

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

The simulation was a valuable learning experience.
• Strongly Disagree (1)
• Disagree (2)
• Neutral (3)
• Agree (4)
• Strongly Agree (5)

The simulation was at an appropriate level of difficulty.
• Strongly Disagree (1)
• Disagree (2)
• Neutral (3)
• Agree (4)
• Strongly Agree (5)

The simulation was at an appropriate level of stress.
• Strongly Disagree (1)
• Disagree (2)
• Neutral (3)
• Agree (4)
• Strongly Agree (5)

I found the material included in the simulation interesting.
• Strongly Disagree (1)
• Disagree (2)
• Neutral (3)
• Agree (4)
• Strongly Agree (5)

The simulation was applicable to my upcoming responsibilities as an intern.
• Strongly Disagree (1)
• Disagree (2)
• Neutral (3)
• Agree (4)
• Strongly Agree (5)

This simulation enhanced my confidence and clinical decision-making skills for the future.
• Strongly Disagree (1)
• Disagree (2)
• Neutral (3)
• Agree (4)
• Strongly Agree (5)

The simulation felt realistic.
• Strongly Disagree (1)
• Disagree (2)
• Neutral (3)
• Agree (4)
• Strongly Agree (5)

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)
- 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)

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

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

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