Laryngospasm Versus Bronchospasm High-Fidelity Simulation

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Date: 1/5/2024

(Abstract)

Laryngospasm and bronchospasm are anesthesia complications that occur commonly in the operating room. Laryngospam and bronchospasm can both lead to hypoxia, hypercarbia, and hemodynamic instability. Our goal was to determine if first year SRNAs would have a better understanding of identifying and treating each complication through a simulation and debrief scenario. We used a pretest to gather baseline knowledge and confidence level followed by a simulation where the subjects were to identify and treat either bronchospasm or laryngospasm. Following the simulation, a debrief was conducted to educate and discuss the simulation using an interactive powerpoint presentation. After the debrief, the same simulation was conducted again. Afterwards, a posttest was administered to determine if an increase in knowledge and confidence was gained. As a result, there was an increase in knowledge and confidence following the simulation and debrief.

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Introduction

Laryngospasm and bronchospasm are known complications of anesthesia. Laryngospasm and bronchospasm can present as persistent coughing and stridor leading to improper oxygenation (Juang et al., 2020). One study showed that airway complications such as laryngospasm and bronchospasm occurred in 40 out of 300 (13%) patients that underwent anesthesia (Juang et al., 2020). While these two complications present similarly clinically, they are physiologically different and are treated differently. Providers must know how to distinctly tell the difference between these two and how they are going to treat them promptly. If the provider is not efficient in treating these emergency situations, the provider is putting the patient's wellbeing at risk. Preparing for these situations starts in training as a Student Registered Nurse Anesthetist (SRNA). While SRNAs are required to meet a certain number of cases before graduating, the Council of Accreditation (COA) recommends further training with the use of simulation (COA, 2020).

Historically, high fidelity simulation training has been utilized by aviation training and the military in order to address skills, communication, and safety in critical situations (Green et al., 2016). Over the years, simulation has made its way into the world of anesthesia. Simulation in anesthesia can be utilized to mimic human responses in a realistic manner such as breathing patterns, heart rate, blood pressure, and even different levels of airway obstruction (Green et al., 2016). This study aims to identify if a high fidelity simulation scenario followed by a debrief will assist SRNAs in feeling more confident and able to identify and treat laryngospasm and bronchospasm.

Background

Laryngospasm is a dangerous situation during anesthesia that causes the vocal cords to spasm in the closed position, thus cutting off the ability to ventilate (Holley et al., 2019). Eventually, this may lead to hypoxia, hypercarbia, and death (Holley et al., 2019). Signs and symptoms of a laryngospasm can occur throughout anesthesia but most often occur during extubation when the airway is not secure and the patient is unable to speak or breathe (Holley et al., 2019). These symptoms include inspiratory stridor, suprasternal and supraclavicular retraction during inspiration, or an absent or altered EtCO2 waveform (Holley et al., 2019). As the vocal cords slowly relax and open, you may hear a high-pitched stridor (Holley et al., 2019).

Treatment for laryngospasm is a combination of jaw thrust at the angle of the mandible (Larson's maneuver) while applying positive pressure ventilation with 100% oxygen (Holley et al., 2019). If the Larson's maneuver & positive pressure fail, administering succinylcholine can break the spasm (Holley et al., 2019). The recommended dose of succinylcholine varys from 0.25 to 1 mg/kg intravenously or 4 mg/kg intramuscularly (Holley et al., 2019). In addition, some texts recommend suctioning foreign material from the oropharynx, administering lidocaine, 1-1.5 mg/kg, and removing or avoiding any painful stimulus (Holley et al., 2019).

Bronchospasm is a reversible reflex spasm of the smooth muscle in the bronchi. Bronchospasm is vagally mediated and caused by histamine, or one of many noxious stimuli including cold air, inhaled irritants, and instrumentation such as tracheal intubation (Gautam & Sharkya, 2019). Signs and symptoms of bronchospasm are high peak inspiratory pressures (PIP) and airway resistance (Gautam & Sharkya, 2019). Manual ventilation will often feel like the air isn't moving, or that you're "hitting a wall" (Gautam & Sharkya, 2019). As a result, bronchospasm leads to wheezing, reduced tidal volumes, reduced dynamic compliance, and

hypoxemia (Gautam & Sharkya, 2019). During anesthesia, this can occur during induction or at any stage throughout the use of anesthesia during surgery (Gautam & Sharkya, 2019).

Treatment for bronchospasm includes 100% oxygen, manual ventilation (to assess pulmonary compliance and to assess any other possible reasons for high circuit pressure), and deepening of sedation (Hines & Marschall, 2018). Deepening of sedation can be accomplished through volatile anesthetics, propofol, ketamine, or a combination of agents (Hines & Marschall, 2018). Short acting beta 2 agonists such as albuterol can also be utilized to treat bronchospasm. If the patient is still spasming, epinephrine can be given (Hines & Marschall, 2018). For epinephrine, best practice is to give judiciously in small increments and wait for reaction (this can sometimes take up to 5 minutes) (Hines & Marschall, 2018). Corticosteroids should be considered for the long-term effects, as these drugs will help very little in acute/emergent situations (Hines & Marschall, 2018). Desflurane and isoflurane can be irritating on the airway, thus sevoflurane is the superior volatile in regards to limiting bronchospasm (Hines & Marschall, 2018).

While signs and symptoms of laryngospasm and bronchospasm are very similar, they are not treated the same (Xiong & Sun, 2019). Both disease processes can have devastating effects on a patient during anesthesia (Xiong & Sun, 2019). For instance, if laryngospasm is not treated efficiently, the patient may develop negative pressure pulmonary edema leading to severe hypoxemia and pulmonary edema (Xiong & Sun, 2019). On the other hand, bronchospasm can increase the patient's pulmonary vascular resistance and lead to hypoxemia and right-sided heart failure (Woods & Sladen, 2009). Anesthesia providers must be ready to recognize the difference between the two and treat promptly for safe anesthetic care (Xiong & Sun, 2019). Building a strong anesthesia foundation starts while in school as an SRNA. By preparing SRNAs with

high-fidelity simulation, the anesthesia trainee can have better confidence in recognizing and providing prompt treatment for either laryngospasm or bronchospasm.

Problem Statement

While SRNAs are taught how to identify and treat laryngospasm and bronchospasm accordingly, experiencing it in real time and knowing what to do in the moment is what makes this concept difficult. When taking a written exam, the SRNA has time to think about the question, gather their thoughts, and choose from given options. In the real world, this is not the case, and the provider must critically think in a timely manner in order to protect the patient. Thus, simulation experiences while in school may lead to increased knowledge and confidence for SRNAs when it comes to facing these issues in the clinical setting. This project seeks to discover if first year SRNAs will grow in knowledge and confidence through a high-fidelity simulation experience coupled with a debrief of the simulation. The simulation will immerse the subjects into a real life scenario requiring knowledge and critical thinking in order to overcome the task at hand. In order to test for statistical significance, the subjects will be asked to complete a pretest before the simulation and a post test after the simulation is complete.

Needs Assessment

The Nurse anesthesia program at a University in the Midwest would benefit from an immersive simulation experience involving laryngospasm and bronchospasm and how to treat accordingly. Currently, first year SRNA students at this university are learning about laryngospasm & bronchospasm in class, but they are not exposed to these scenarios in a simulation activity. However, studies have shown that students who receive simulation experience in addition to didactic learning acquire significantly higher skill levels of knowledge and confidence compared to those with didactic alone (Bowling & Underwood, 2016).

Laryngospasm and bronchospasm are not uncommon, with laryngospasm occurring in every 2.5% of cases with emergence (Chambers, 2020). On the other hand, the incidence of bronchospasm is 2% in asthmatic patients and an overall incidence of 0.2% (Vojdani, 2018). It is imperative that nurse anesthetists are equipped with the knowledge and skills to identify and manage life-threatening situations. Therefore, it is important to prepare future anesthesia providers for when these life threatening situations arise.

Aims and Objectives

The aim of this project is to identify if the first year SRNAs feel knowledgeable and confident in identifying and treating laryngospasm and bronchospasm following a simulation experience with a debrief of the simulation. The confidence and knowledge levels will be accessed with a posttest after a high fidelity simulation to gauge whether or not the simulation experience increases knowledge and confidence. The high fidelity simulation scenario will be designed and presented to the first year SRNAs by two junior SRNAs. The simulation and evaluation will be carried out from January 15, 2023 to May 5, 2023. The objectives of this project are:

- Gauge first year SRNA confidence in identifying laryngospasm and bronchospasm.
- Gauge first year SRNA knowledge on how to properly identify and treat both laryngospasm and bronchospasm.
- If statistically significant, discuss implementing the simulation experience to future cohorts.
- Identify whether a debrief increases knowledge of identification and treatment of laryngospasm and bronchospasm.

Theoretical Framework

Achieving optimal evidence-based practice is imperative in the realm of healthcare. With healthcare constantly changing and the creation of new technology/ methods, discovering best practice through research will continue to be pertinent. In the early 1990s, a team of nurses from the University of Iowa developed a framework called the Iowa Model of Research (Buckwalter et al., 2017). The Iowa Model (see APPENDIX A) provides a pathway or method to evidence-based practice (Buckwalter et al., 2017). Essentially, it is a guide laid out in steps that allows the researchers to carry out evidence based practice in the appropriate manner in order to improve the quality of care. It involves identifying a trigger, determining if the problem is a priority, forming a team, and gathering and analyzing research (Buckwalter et al., 2017). Next, the researchers critique and synthesize the research and decide whether or not there is sufficient research in order to implement the change (Buckwalter et al., 2017). Next the model includes implementing change within a chosen sample size followed by evaluating the results and deciding whether or not the change is statistically warranted (Buckwalter et al., 2017).

For this project, we identified an issue after we felt underprepared as first year SRNAs on how to identify and treat bronchospasm and laryngospasm. Then, we decided that this issue is a priority due to the prevalence of bronchospasm and laryngospasm and the repercussions that can ensue. The team we gathered involves the two of us junior SRNA students, a chair, and a board member who has access to the high-fidelity simulation lab. Next, we gathered and analyzed research and decided that there was sufficient enough data on the prevalence of bronchospasm and laryngospasm as well as the lack of treatment confidence. In addition, we found data supporting the use of simulation in order to increase confidence and knowledge. Going forward, we will choose a sample size including first year SRNA students at a University in the midwest

and gauge whether or not a high fidelity simulation experience will statistically improve knowledge and confidence. After gathering the results, it will be decided as to whether or not this should be integrated into the curriculum of current first year SRNAs at this institution.

GANTT Chart

The GANTT chart (see Appendix B) provides a timeline for how we plan to carry out and complete the study.

SWOT Analysis

The key stakeholders of the project are first year SRNA students as well as future patients who will benefit from stronger anesthesia providers. The strengths of the project are the use of a high fidelity simulation lab and cooperation by the SRNA students. Potential barriers include time restraints for both the subjects and research conductors due to full time course loads and clinical obligations . Opportunities for this project include increased knowledge and confidence, thus stronger anesthesia providers. Potential threats to this project include skewed data from the first year SRNA students rushing to fill out the pre and post tests. Table of full SWOT analysis is presented in APPENDIX C.

Literature Review

Results

The literature review was conducted throughout October and November 2022 using Pubmed and Medline EBSCO databases to assess various articles in regards to the effectiveness of simulation as a learning tool. The key words used in the search include *effects, outcomes, simulation, high-fidelity, manifestations, SRNA, medical, nursing, anesthetists, students, knowledge,* and *confidence*. The BOOLEAN phrases used in the search include simulation OR

high-fidelity simulation OR role-playing OR knowledge OR confidence . As a result of the database searches, 203 articles were provided as seen in the PRISMA flowchart (appendix E). After reducing the search to the last five years and randomized controlled trials, 53 articles remained. Next, the articles were examined for the inclusion criteria of only pertaining to simulation rather than videos or virtual reality. Then, several articles unrelated to healthcare were thrown out. From that, the 11 remaining randomized control articles were selected that display the effects or lack thereof of simulation experience on boosting knowledge and confidence. The matrix containing basic information on the 11 selected articles can be found in appendix D.

Anesthesia-related articles

Of the 11 articles selected, five of them tested for significance with simulation-based training among anesthesia-related skills. One of the articles had 104 subjects and utilized a questionnaire to see if there was statistical significance in crisis management for those partaking in the simulation versus just observing. As a result, both groups improved while those partaking in simulation had improved scores versus those just observing. Another article studied the effects of simulation on performance using transesophageal echocardiography versus those doing an online module. Posttest scores were significantly higher for those in the simulation group ($P<0.01$). Two of the articles studied whether or not simulation would improve CPR performance and adequacy and both displayed statistical significance in improvement scores from pretest to posttest. In one of these, 51.9% of the subjects from the experimental group met the criteria for adequate CPR whereas only 12.5% from the control group met criteria. In another study, the researchers were able to find that simulation improved ultrasound skills in anesthesia students. This study examined the performance scores using the Objective Structured

Assessment of Ultrasound Skills (OSAUS) and showed that the performance scores for the simulation group were significantly higher than the non-simulation group.

Non-anesthesia Related Articles

Of the selected 11 articles, six of them are unrelated to anesthesia but still pertain to healthcare in genreal. One of the articles tested for significance in whether or not simulation would improve knowledge and critical thinking with the management of preeclampsia. From this study, knowledge ($p<0.001$), critical thinking ($p<0.05$), and decision making ($p <0.05$) were all increased for those in the experimental group. Another article studied nursing students to see if a simulation would improve their knowledge on nursing ethics principles. In this study, the control group still received education on ethics but it was in more of a traditional lecture setting. As a result, nursing knowledge improved for both groups, however the simulation was no more statistically significant. Another study testing the significance in a simulated cerebral spinal drainage catheter insertion showed no significance ($P=0.48$) compared to the control group. One study involving nursing students tested for significance in a simulation to improve skill and anxiety levels when it comes to cardiac auscultation. The results show that simulation compared to traditional teaching was more effective ($P<0.001$). An article involving medical residents illuminated whether simulation is superior to lecture-style teaching in regards to hospital orientation. This study did not show that one method is superior to the other. Finally, the last article we found involved extracorporeal membrane oxygenation (ECMO) and supported the idea of simulation being a more effective teaching method versus traditional teaching.

Project Design

The research design for this project is going to be an educational project design. This design was chosen due to the need for further education on the identification and treatment of

laryngospasm and bronchospasm by the first year SRNA students. The project is being conducted with first year SRNA students in a high-fidelity simulation lab. The measurement tools planned on being used are a pretest, a high-fidelity simulation lab, debrief, final simulation, and a posttest. Data collection procedures will be based on the pretest and posttest results. Ethical considerations and protection of humans in the study will make sure the simulation environment is a safe, non threatening environment for them to attempt to identify and treat laryngospasm and bronchospasm accordingly. The pre and post test will be done with no identifiers except the last four digits of their student ID number (provided by their campus identification card) for comparison of the results. The pre and post test number will be made known to the participants so they are fully aware that the results will be compared.

Population and Setting

The population selected to participate in this educational project is 20 first year SRNA students. The setting will be located in a high-fidelity simulation lab at a small Catholic university in the midwest United States. This study will take place between February and March 2023.

Measurement Instruments

A pre and post test will be used to measure applicability of the project. The pre and post test consists of select multiple, select one, true and false, and likert scale style questions (see Appendix F). There are 14 questions on the pretest and 16 questions on the posttest. Two additional questions are on the posttest to gauge a better understanding of the subject's feelings of the simulation as a whole.

Data Collection Procedures

The first year SRNA students will be given a pre test that they will be asked to fill out.

The pre and post tests will be given without any outside factors for assistance, no open book, and will be answered individually. After the high-fidelity simulation has occurred, they will be asked to fill out a post test. The pre and post test will be compared to each other to identify if the project design was effective or not.

Ethical considerations

Ethical considerations that will be implemented to ensure anonymity will include refraining from putting their name on the pre and post test. Instead they will be asked to provide their last four digits of their student identification number so the pre and post test can be compared and analyzed. IRB approval will also be gained to ensure the project design to protect the human subjects.The participants of the study will be instructed they can leave the study at any point without any repercussions. The pre and post test will be stored together with the authors at all times on a password-protected computer that only the authors have access to. The data collected will be kept for two years.

Project Evaluation Plan

The effectiveness of the project will be determined based on answers from our post simulation test. It will be determined if the students feel more knowledgeable and confident about identifying and treating laryngospasm and bronchospasm. Additionally, the post simulation test will identify if they are able to answer questions correctly concerning laryngospasm and bronchospasm recognition and treatment. The test will be compared to the results from the pretest given before the simulation for statistical significance. To maintain validity, the tests will be taken before and after the simulation with the proctors present to ensure sharing of information is prohibited. After the pre and post test and simulation have been conducted,

analysis will be performed to identify if the P-value is equal to or less than 0.05 to be considered statistically significant.

Quantitative Results

A statistical hypothesis test using a one sample T-Test was used to determine if there was statistical significance when comparing the pretest and posttest results in regards to knowledge improvement. Fourteen SRNAs completed the pre test, participated in the simulation and debrief, then completed the post test. The P-value of the quantitative questions was <0.001, showing that the study was significant. The following table provides the associated mean presented as the t-values for the pre and post test followed by the significant p values.

One Sample T-Test

		Statistic	df	p
Pre Test Quantitative	Student's t	28.8	13.0	< .001
Post Test Quantitative	Student's t	53.9	13.0	< .001

Note. H_a $\mu \neq 0$

Qualitative Results

A statistical hypothesis test using a one sample T-Test was used to determine if there was statistical significance when comparing the pretest and posttest results in regards to confidence improvement. 14 SRNAs answered the pretest, underwent the simulation and debrief, then completed the post test. The P-value of the qualitative questions was <0.001, showing that the study was significant. The table below provides the associated mean represented by the t-values for the pre and post test followed by the significant p values.

One Sample T-Test

		Statistic	df	p
Pre Test Qualitative	Student's t	7.81	13.0	< .001
Post Test Qualitative	Student's t	32.27	13.0	< .001

Note. H_a μ ≠ 0

Discussion

The results from the post test compared to the pretest display significant improvement in knowledge and confidence following the simulation experience. Each question on the pre and post test was evaluated in order to reach this conclusion. This project strengthens the idea that SRNAs can improve knowledge and confidence through simulation & debrief when dealing with stressful situations during anesthesia. The idea of a simulation and debrief can be applied to endless scenarios for educational purposes.

Strengths and Limitations

The project's strengths include participation and knowledge base from the freshmen SRNAs. In addition, strengths included access to a high fidelity simulation lab to carry out the simulation. Limitations were having a different number of participants that did the pre test and the post test. Another limitation was changing of faculty in the middle of the project.

Conclusion

The project's aims was to determine if a simulation with debrief would increase first year SRNAs comfort and ability to identify and treat laryngospasm and bronchospasm. A simulation that required the SRNAs to identify and treat both laryngospasm and bronchospasm was

implemented. Following the simulation, a debrief was conducted to discuss the differences and identification as well as treatment for both. The debrief included a powerpoint presentation explaining bronchospasm and laryngospasm. After the debrief, the SRNAs were asked to perform the simulation again. There was a pre test and post test to see if the SRNAs knowledge and confidence improved. The results were significant with a P-value of $<.001$. To further benefit SRNAs moving forward, this training can be added into the simulation curriculum for first year SRNAs at this institution. In addition, the same simulation design can be used for various situations anesthetists may encounter in the operating room. Further educational projects should be completed with larger sample sizes for comparison.

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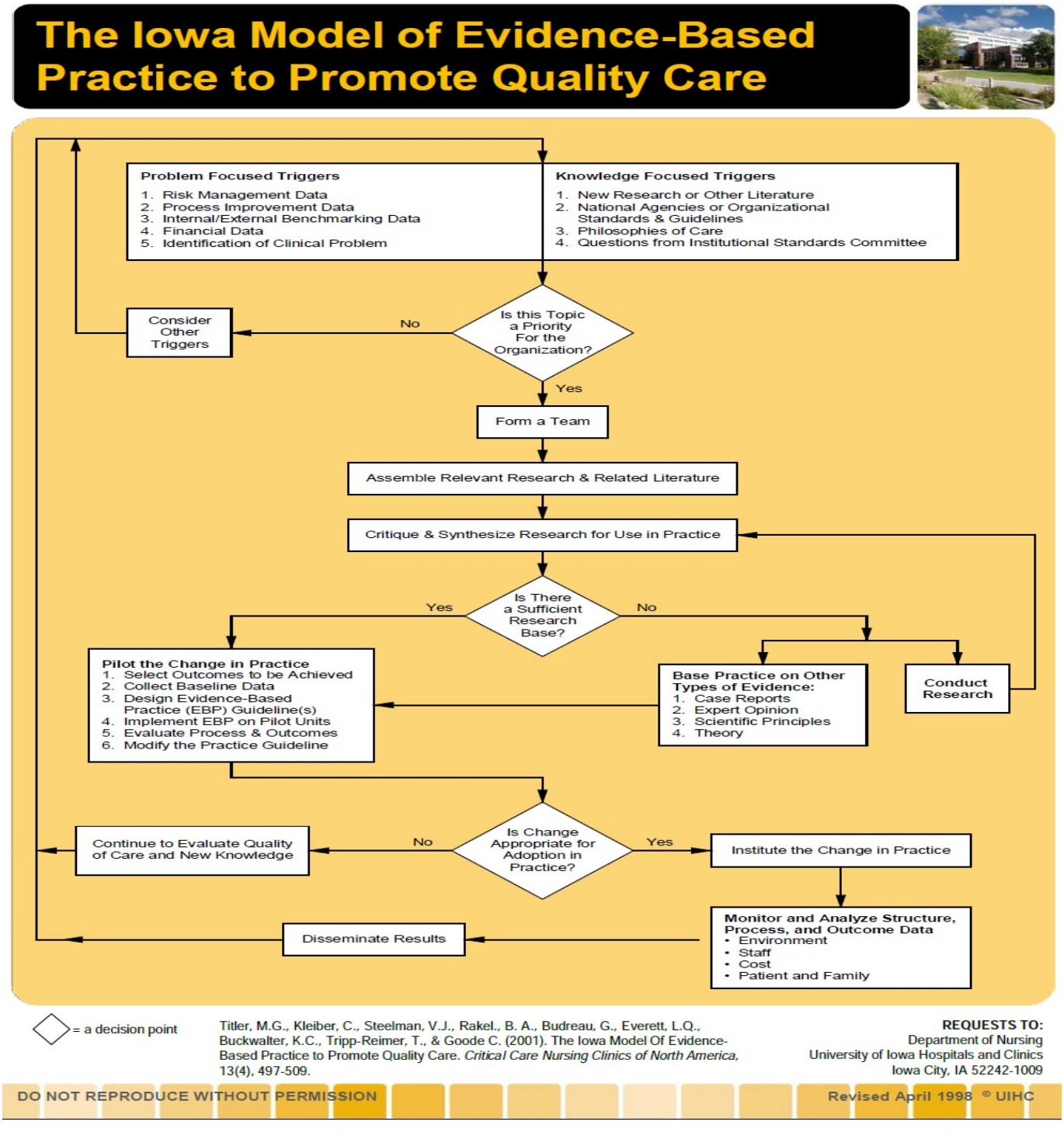
Appendix A


The Iowa Model of Evidence-Based Practice to Promote Quality Care
Problem Focused Triggers
1. Risk Management Data
2. Process Improvement Data
3. Internal/External Benchmarking Data
4. Financial Data
5. Identification of Clinical Problem
Knowledge Focused Triggers
1. New Research or Other Literature
2. National Agencies or Organizational Standards & Guidelines
3. Philosophies of Care
4. Questions from Institutional Standards Committee
Is this Topic a Priority For the Organization?
No
Consider Other Triggers
Yes
Form a Team
Assemble Relevant Research & Related Literature
Critique & Synthesize Research for Use in Practice
Is There a Sufficient Research Base?
Yes
No
Pilot the Change in Practice
1. Select Outcomes to be Achieved
2. Collect Baseline Data
3. Design Evidence-Based Practice (EBP) Guideline(s)
4. Implement EBP on Pilot Units
5. Evaluate Process & Outcomes
6. Modify the Practice Guideline
Base Practice on Other Types of Evidence:
1. Case Reports
2. Expert Opinion
3. Scientific Principles
4. Theory
Conduct Research
Is Change Appropriate for Adoption in Practice?
No
Yes
Continue to Evaluate Quality of Care and New Knowledge
Institute the Change in Practice
Monitor and Analyze Structure, Process, and Outcome Data
• Environment
• Staff
• Cost
• Patient and Family
Disseminate Results
= a decision point
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Appendix B

August 1, 2022	**Identified a need for education about Laryngospasm and Bronchospasm**
August 1-15, 2022	**Literature Review Conducted**
August 15, 2022	**Identified who needed education and how to present the Information**
September 20, 2022	**Project Chair selected and confirmed**
October 1, 2022	**Project Approved by Chair and Program Director**
October 24, 2022	**Introduction, Background, Problem statement, and Needs assessment written**
November 14, 2022	**Aims and Objectives, Theoretical concepts, Gantt Chart, and SWOT Analysis written**
December 5, 2022	**Project Design/ Methods December 5, 2022** **Evaluation Plan**
January 9, 2023	**Revised Project Proposal**
January 13, 2023	**IRB Submission**

March 12, 2023	**Data Collection**
March 20, 2023	**Data Analysis**
March 27, 2023	**Complete Academic Paper Draft**
March 31, 2023	**Complete Executive Summary**
April 10, 2023	**Poster Presentation**
April 17, 2023	**Final Project Report**

Appendix C

Strengths	**Weakness**
● Access to high Fidelity Simulation Lab ● First year SRNA cooperation & willingness to learn ● First-hand access and assistance from the simulation instructor	● Junior SRNA time Constraints ● First year SRNA time Constraints ● Potentially small sample size
Opportunities	**Threats**
● Increased knowledge and confidence to first year SRNA students in regards to laryngospasm and bronchospasm ● Potential curriculum change for future cohorts ● Increased patient outcomes due to higher knowledge and confidence	● Skewed Data from hurried participation ● Limited simulation time ● Lack of participation in general

Appendix D

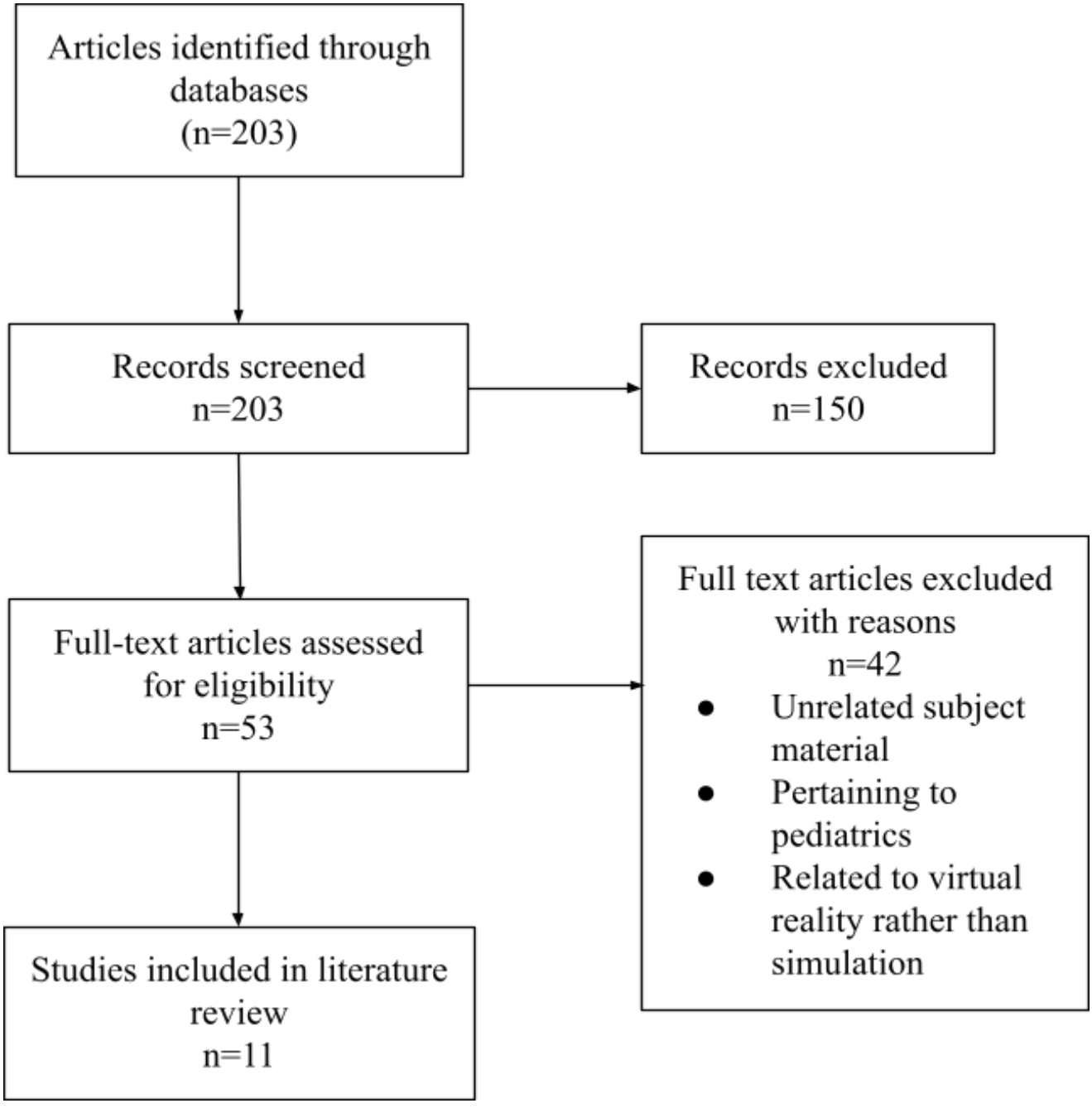
Citation	Research Design & Level of Evidence	Population / Sample size n=x	Major Variables	Instruments / Data collection	Results
Akalin, A., & Sahin, S. (2020). The impact of high-fidelity simulation on knowledge, critical thinking, and clinical decision-making for the management of pre-eclampsia. *International journal of gynaecology and obstetrics: the official organ of the International Federation of Gynaecology and Obstetrics*, *150*(3), 354–360. https://doi.org/10.1002/ijgo.13243	Randomized control trial; level 2	n=107	The students in the experimental group attended the simulation training using a high-fidelity simulator, while the students in the control group attended only the classical training on "the management of pre-eclampsia	Pretest vs. posttest after intervention	Knowledge (P<0.001), critical thinking (P<0.05), and clinical decision-making (P<0.05) scores of students in the experimental group increased after the simulation.
Donnelly, M. B., Horsley, T. L., Adams, W. H., Gallagher, P., & Zibricky, C. D. (2017). Effect of Simulation on Undergraduate Nursing Students' Knowledge of Nursing Ethics Principles. *The Canadian journal of nursing research = Revue canadienne de recherche en sciences infirmieres*, *49*(4), 153–159. https://doi.org/10.1177/0844562117731975	Randomized control trial; level 2	n=154	Those in the experimental group participated in a 1 hour ethics consultation simulation whereas the control group watched a video.	Pretest vs posttest after intervention	Nursing students' knowledge of nursing ethics principles significantly improved from pre-test to post-test (p = .002); however, there was no significant difference between the experimental and control groups knowledge scores (p = .13).
Vural Doğru, B., & Zengin Aydın, L. (2020). The effects of training with simulation on knowledge, skill and anxiety levels of the nursing students in terms of cardiac auscultation: A randomized controlled study. *Nurse education today*, *84*, 104216. https://doi.org/10.1016/j.nedt.2019.104216	Randomized control trial; level 2	n=72	The students in the simulation group received a cardiac auscultation training by using a high-fidelity simulator while the students in the control group received training with the traditional teaching method	Knowledge Assessment Form for Cardiac Auscultation, Skill Evaluation Form for Cardiac Auscultation and State Anxiety Inventory..	It was found that the high-fidelity simulator method was more effective than the traditional teaching method to increase the students' knowledge (p = 0.001) and skill (p < 0.001) levels.
Blanié, A., Gorse, S., Roulleau, P., Figueiredo, S., & Benhamou, D. (2018). Impact of learners' role	Randomized	n=104	The subjects were divided into	Questionnaire	This study suggests an immediate improvement of

(active participant-observer or observer only) on learning outcomes during high-fidelity simulation sessions in anesthesia: A single center, prospective and randomized study. *Anesthesia, critical care & pain medicine*, *37*(5), 417–422. https://doi.org/10.1016/j.accpm.2017.11.016	control trial; level 2		either an active participation role or an observer.		learning outcomes for both roles after immersive simulation.
Argalious, M., Trombetta, C., Makarova, N., Saasouh, W., & Rajan, S. (2019). Simulation Versus Problem Based Learning for Cerebrospinal Drainage Catheter Insertion and Management: A Randomized Trial in a Large Academic Anesthesiology Residency Program. *Journal of cardiothoracic and vascular anesthesia*, *33*(4), 993–1000. https://doi.org/10.1053/j.jvca.2018.07.033	Randomized control trial; level 2	n=28	Out of 28 residents who completed the study, 13 were randomized to simulation-based learning and N = 15 residents to the traditional approach.	Anesthetists non-technical skills (ANTS) global rating score.	Compared to traditional learning, simulation-based learning does not result in a statistically significant improvement in anesthesia resident performance during insertion and management of cerebrospinal fluid drainage catheters.
Shields, J. A., & Gentry, R. (2020). Effect of Simulation Training on Cognitive Performance Using Transesophageal Echocardiography. *AANA journal*, *88*(1), 59–65.	Randomized control trial; level 2	n=71	71 student registered nurse anesthetists were randomly assigned to either web-based or simulator-based TEE training	Pretest/ posttest comparison post intervention	Posttest scores were significantly higher in all 3 cognitive categories in the simulator group compared with the online group (P < .01.
McCoy, C. E., Rahman, A., Rendon, J. C., Anderson, C. L., Langdorf, M. I., Lotfipour, S., & Chakravarthy, B. (2019). Randomized Controlled Trial of Simulation vs. Standard Training for Teaching Medical Students High-quality Cardiopulmonary Resuscitation. *The western journal of emergency medicine*, *20*(1), 15–22. https://doi.org/10.5811/westjem.2018.11.39040	Randomized control trial; level 2	n=70	70 fourth-year medical students to either simulation or standard training.	Kruskal-Wallis rank sum test	Students in the SIM group performed CPR that more closely adhered to the AHA guidelines of compression depth and compression fraction
Yamamoto, A., Obika, M., Mandai, Y., Murakami, T., Miyoshi, T., Ino, H., Kataoka, H., & Otsuka, F. (2019). Effects on postgraduate-year-I residents of simulation-based learning compared to traditional lecture-style education led by postgraduate-year-II residents: a pilot study. *BMC medical education*, *19*(1), 87.	Randomized control trial; level 2	n=76	The study enrolled 76 residents, who were randomized into two groups: simulation and lecture groups.	pretest / posttest after intervention.	There was no statistical significance in regards to improved test scores between the simulation and lecture groups.

https://doi.org/10.1186/s12909-019-1509-y					
Gannon, W. D., Stokes, J. W., Pugh, M. E., Bacchetta, M., Benson, C., Casey, J. D., Craig, L., Semler, M. W., Shah, A. S., Troutt, A., & Rice, T. W. (2022). Simulation Versus Interactive Mobile Learning for Teaching Extracorporeal Membrane Oxygenation to Clinicians: A Randomized Trial. *Critical care medicine*, *50*(5), e415–e425. https://doi.org/10.1097/CCM.0000000000005376	Randomized control trial; level 2	n=44	Participants were randomized to receive either simulation training, training with quizzes, or no training.	The primary outcome was knowledge about extracorporeal membrane oxygenation assessed by score on the immediate post intervention written examination	Simulation was superior to quiz training and no training in regards to extracorporeal membrane oxygenation knowledge acquisition.
Østergaard, M. L., Rue Nielsen, K., Albrecht-Beste, E., Kjær Ersbøll, A., Konge, L., & Bachmann Nielsen, M. (2019). Simulator training improves ultrasound scanning performance on patients: a randomized controlled trial. *European radiology*, *29*(6), 3210–3218. https://doi.org/10.1007/s00330-018-5923-z	Randomized control trial; level 2	n=20	Students were randomly assigned to either the simulation-based group or no intervention.	Performance scores assessed using Objective Structured Assessment of Ultrasound Skills (OSAUS)	The study showed improved performance in diagnostic ultrasound scanning on patients after simulation-based mastery learning for radiology residents.
Berger, C., Brinkrolf, P., Ertmer, C., Becker, J., Friederichs, H., Wenk, M., Van Aken, H., & Hahnenkamp, K. (2019). Combination of problem-based learning with high-fidelity simulation in CPR training improves short and long-term CPR skills: a randomised single blinded trial. *BMC medical education*, *19*(1), 180. https://doi.org/10.1186/s12909-019-1626-7	Randomized control trial; level 2	n=112	The experimental group partook in a 45 minute high-fidelity CPR simulated training.	Pre and post intervention questionnaire comparison of results.	51.9% of the intervention group met the criteria of sufficiently performed CPR as compared to only 12.5% in the control group on the day of the intervention ($p = 0.007$).

Appendix E

PRISMA 2009 Flow Diagram



Appendix F

Last 4 Digits of Badge Number:

Pretest

1. On a scale 1-5, 1 being the lowest and 5 being the highest, how confident are you in identifying the difference between laryngospasm and bronchospasm?

1

2

3

4

5

2. What commonly occurs because of sensory stimulation of the vagus nerve via the internal branch of the superior laryngeal nerve?

A. Laryngospasm

B. Bronchospasm

3. When a bronchospasm occurs, the afferent response causes spasm and closing of the vocal cords from the external branch of both the superior laryngeal nerve and the recurrent laryngeal nerve. True or False.

A. True

B. False

4. Which muscles are responsible for closing of the vocal cords during a laryngospasm? (Select 2)

   A. Lateral Cricoarytenoid Muscle

   B. Interarytenoid

   C. Cricothyroid

   D. Thyroarytenoid

5. Treatment for Laryngospasm include all of the following except?

   A. Administer 80% FIO2

   B. Remove stimulus

   C. Larson Maneuver

   D. Positive pressure ventilation 10-30 cm H2O

   E. Succinylcholine .2-2 mg/ kg IV or 4-5 mg/ kg IM

   F. Deepen Anesthetic

6. If left untreated, Laryngospasm can result in? Select 2

   A. Hypoxia

   B. Negative- pressure pulmonary edema

   C. Coagulopathy

   D. Hypothermia

7. What Guedel stage should a patient be extubated to prevent a laryngospasm from occurring

   A. Guedel Stage 1

   B. Guedel Stage 2

   C. Guedel Stage 3

D. Either Guedel Stage 1 or 3

8. Causes of intraoperative Bronchospasm include all of the following except:

A. Airway manipulation

B. Chronic exposure to allergies

C. Stress of surgery

D. Asthmatic episode

9. Identify signs and symptoms of Bronchospasm. (Select 2)

A. Wheezing

B. Low inspiratory pressures

C. Decreased EtCO2

D. Decreased PACO2

10. Identify the treatment for Bronchospasm

A. Administer 100% FIO2

B. Deepen Anesthetic

C. Short acting B2 agonist

D. Epinephrine 1 mcg/ kg

E. Aminophylline

F. All the Above

11. Why is use of a paralytic not a viable option for Bronchospasm treatment?

A. They often make the bronchospasm worse

B. Administration may be difficult

C. Paralytics do not work on smooth muscle

D. Only nebulized paralytics will be effective

12. What reversal agent is preferred in a patient with a reactive airway

A. Neostigmine/ Glycopyrrolate

B. Edrophonium/ Atropine

C. Sugammadex

13. What Electrolyte imbalance can cause laryngospasm? Select 2

A. Hypernatremia

B. Hypocalcemia

C. Hypomagnesemia

D. Hypercalcemia

E. Hyperkalemia

14. Signs of laryngospasm include all of the following except:

A. Suprasternal & supraclavicular retraction during expiration

B. “Rocking horse” appearance of the chest wall

C. Lower rib flailing

D. Inspiratory stridor

E. Absent or altered EtCO2 waveform

Last 4 Digits of Badge Number:

Post Test

1. On a scale 1-5, 1 being the lowest and 5 being the highest, how confident are you in identifying the difference between laryngospasm and bronchospasm?

1

2

3

4

5

2. What commonly occurs because of sensory stimulation of the vagus nerve via the internal branch of the superior laryngeal nerve?

A. Laryngospasm

B. Bronchospasm

3. When a bronchospasm occurs the afferent response causes spasm and closing of the vocal cords to occur from the external branch of both the superior laryngeal nerve and the recurrent laryngeal nerve? True or False.

A. True

B. False

4. Which muscles are responsible for closing of the vocal cords during a laryngospasm? (Select 2)

A. Lateral cricoarytenoid Muscle

B. Interarytenoid

C. Cricothyroid

D. Thyroarytenoid

5. Treatment for Laryngospasm includes all of the following except?

A. Administer 80% FIO2

B. Remove stimulus

C. Larson Maneuver

D. Positive pressure ventilation 10-30 cm H2O

E. Succinylcholine .2-2 mg/ kg IV or 4-5 mg/ kg IM

F. Deepen Anesthetic

6. If left untreated, laryngospasm can result in? Select 2

A. Hypoxia

B. Negative- pressure pulmonary edema

C. Coagulopathy

D. Hypothermia

7. What Guedel stage should a patient be extubated to prevent a laryngospasm from occurring?

A. Guedel Stage 1

B. Guedel Stage 2

C. Guedel Stage 3

D. Either Guedel Stage 1 or 3

8. Causes of intraoperative Bronchospasm include all of the following except.

   A. Airway manipulation

   B. Chronic exposure to allergies

   C. Stress of surgery

   D. Asthmatic episode

9. What are the signs and symptoms of Bronchospasm? (Select 2)

   A. Wheezing

   B. Low inspiratory pressures

   C. Decreased EtCO2

   D. Decreased PACO2

10. What is the appropriate treatment for Bronchospasm?

   A. Administer 100% FIO2

   B. Deepen Anesthetic

   C. Short acting B2 agonist

   D. Epinephrine 1 mcg/ kg

   E. Aminophylline

   F. All the Above

11. Why is use of a paralytic not a viable option for Bronchospasm treatment

   A. They often make the bronchospasm worse

   B. Administration may be difficult

C. Paralytics do not work on smooth muscle

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A. Neostigmine/ Glycopyrrolate

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A. Hypernatremia

B. Hypocalcemia

C. Hypomagnesemia

D. Hypercalcemia

E. Hyperkalemia

14. Signs of laryngospasm include all of the following except:

F. Suprasternal & supraclavicular retraction during expiration

G. “Rocking horse” appearance of the chest wall

H. Lower rib flailing

I. Inspiratory stridor

J. Absent or altered EtCO2 waveform

15. On a scale 1-5, 1 being the least confident and 5 being the most confident, after a high-fidelity simulation, how do you feel about identifying and treating laryngospasm and bronchospasm?

1

2

3

4

5

16. On a scale of 1-5, 1 being the least confident and 5 being the most confident, did the use of a High-Fidelity Simulation advance your understanding of Bronchospasm and Laryngospasm?

1

2

3

4

5