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Educational Process Improvement Program for Novice Anesthesia Providers Learning Safe Management of The Anesthesia Workstation

Robert M. Vitale
La Salle University, vitaler1@lasalle.edu

James Mahon
La Salle University, mahonj2@lasalle.edu

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James Mahon

Robert Vitale

Abstract

Patient safety is at the cornerstone of the delivery of quality anesthesia. A historically pervasive patient safety threat related to the field of anesthesia has been the anesthesia workstation. Although anesthesia delivery improvements are based on refining physical engineering principles, they are also based on preventing human error. This DNP project uses an educational process improvement design to generate an evidence-based simulation educational activity for novice anesthesia providers to better prepare themselves for the reality of anesthesia workstation malfunction and human error.

Keywords: Patient safety, novice nurse anesthetist, anesthesia workstation, educational process improvement program, simulation-based educational activity, teaching plans

Anesthesia workstations have significantly improved since their inception, and improvements have been driven by various patient safety threats that have arisen (Subrahmanyam & Mohan, 2013). Although workstation improvements are based on refining physical engineering principles, they are also primarily based on preventing human error. According to Mehta (2013), the majority (85%) of all closed claims referencing workstations involved provider error, and 35% of claims were judged preventable if anesthesia providers had performed pre-anesthesia workstation checks.

Formerly, researchers have analyzed reports of anesthesia-related human errors and related them to equipment failure (Cooper et al. 1984). According to Kee et al. (2006), a case report of a typical surgical case in which anesthetic gas was used, anesthesia providers identified a malfunction that could lead to patient complications. In this case report, the workstation was a Drager Narkomed, a standard workhorse in American anesthesia practice (Kee et al., 2006).

During the exemplar case, the anesthesia team could turn on two anesthetic gases simultaneously. Consequently, all modern anesthesia workstations do not allow this problem to happen due to a safety mechanism. However, if this safety mechanism fails, anesthesia providers must be equipped to detect and address this malfunction to avoid delivering two anesthetic gases at once, resulting in a patient safety threat. Fortunately, the mistake was noticed as two different people turned on each gas. Kee et al. (2006) also discussed the near-miss malfunction of the anesthesia workstation's vaporizer locking system. This mistake would have resulted in the increased risk of too much anesthetic gas leading to intraoperative, postoperative complications, and possibly death. Also, the contamination aspect of mixing volatile anesthetics would have led to additional patient problems. (Kee et al. 2006).

Mehta (2013) analyzed patient injuries related to gas delivery equipment claims from the American Society of Anesthesiologists Closed Claims Project database from the 1970s to the 2000s. The authors found that claims decreased over decades, and outcomes became less severe as technological advancements continued. Still, provider error contributes to adverse events, as does a failure to complete a full mechanical check before anesthesia delivery (Mehta et al., 2013). Also, Cooper et al. (1984) looked at a total of 1,089 preventable critical incidents. They found that the most frequently reported issues involved neglecting to notice breathing circuit disconnections, gas-flow control errors, and gas supply loss.

The components of the anesthesia workstation vary depending on age, manufacturer, and model. The differences between older anesthesia workstations (Ohmeda Modulus, Excel, ADU, Aestiva, and the Drager Narkomed, GS, Mobile, MRI, 2B, 2C, 3, or 4) are fewer than their similarities (Tharp, 2014). However, these older workstations are becoming less common and are slowly being phased out as manufacturers stop supporting technical services (Tharp, 2014). The newest anesthesia workstation models have more clinical impact than the previous anesthesia workstations because of the higher degree of computer-controlled systems, physiologic monitors, workstation monitors, and electronic medical record integration (Tharp, 2014).

Novice nurse anesthetists are trained didactically and clinically through standardized checkout procedures provided by the American Society of Anesthesiologists (ASA). In addition, the ASA provides institutional guidelines for developing institution-specific checkout procedures before the delivery of anesthesia (ASA Committee on Equipment and Facilities Task Force, 2008). ASA requirements for safe delivery of anesthesia care include ensuring that there is a reliable source and delivery of oxygen at any appropriate concentration up to 100%, a reliable means of positive pressure ventilation, backup ventilation equipment available and functioning, controlled release of positive pressure from the breathing circuit, anesthesia vapor delivery, adequate suction, and a means to conform the standards for patient monitoring (ASA Committee on Equipment and Facilities Task Force, 2008). These items are categorized into two safety checklists that verify each competent of the anesthesia workstation (ASA Committee on Equipment and Facilities Task Force, 2008). One safety checklist to be completed daily, and another checklist to be completed before each procedure requiring anesthesia (ASA Committee on Equipment and Facilities Task Force, 2008). At certain facilities there are different anesthesia workstations in use and the type of anesthesia workstation varies from facility to facility. This becomes an added potential for safety threats due to the lack of familiarity within the hospital and the different anesthesia workstations.

Human error, anesthesia workstation malfunction, and failure to follow protocols remain safety threats. For example, neglecting to follow the ASA's (2008) pre-anesthesia recommendations for an anesthesia checkout may result in an anesthesia mishap. An anesthesia providers inability to quickly interpret and address a developing anesthesia workstation malfunction could result in patient harm. Also, an anesthesia provider lacking proper backup equipment or lacking the knowledge on when to use such equipment could result in patient harm.

Needs Assessment

Despite improvements in the anesthesia workstation designs and equipment, safety threats and errors continue. Anesthesia workstations have evolved to a point that one checkout procedure is not applicable to all anesthesia delivery systems currently on the market (Feldman et al., 2008). Guidelines can serve as a template for developing checkout procedures that are appropriate for each individual anesthesia machine design and practice setting rather than offering standardized items (Feldman et al., 2008). There is a need for the development of additional educational programs for novice anesthesia providers aimed at reducing patient safety threats and errors related to the use of the anesthesia workstation. The primary aim for this project is to develop an evidence-based educational process improvement program to evaluate if a simulation-based activity will increase the competency level of novice anesthesia providers in identifying and reducing safety threats in the use of anesthesia workstations.

Problem

Human error, as described by Oster and Braaten (2018), "refers to inadvertently making an error or doing something that should not have been done" (p. 403). Specific human factors range from administering anesthetics and include environmental, organizational, and individuals involved in anesthesia delivery (Oster & Braaten, 2018). Therefore, in the context of human factors and the challenges associated with safety practices used with anesthesia workstations, this Doctor of Nursing Practice Project will create an educational process improvement program for novice anesthesia providers learning mastery of anesthesia workstations. In addition, anesthesia providers are focused on preventing future safety concerns related to anesthesia workstations. This educational process improvement program addresses research related to anesthesia workstation alarms of the anesthesia workstation's specific purposes and functions through simulated anesthesia malfunctions requiring rapid and correct responses by anesthesia providers.

Purpose

The purpose of this project will be to create an educational process improvement program to standardize the education of novice anesthesia providers to prevent safety threats related to the anesthesia delivery workstation.

Project Question

What is the evidence to support the creation and validation of an educational process improvement program to improve novice anesthesia providers competency to prevent safety threats regarding the anesthesia workstation?

Conceptual definitions

Anesthesia workstations are defined as devices that deliver a precise but variable gas mixture made of life-sustaining and anesthetizing gases (Tharp, 2014). Therefore, the anesthesia workstation is also known as the anesthesia delivery system (Tharp, 2014).

Nurse anesthetists are highly skilled practitioners in the field of anesthesiology (ASA, 2014). The education of nurse anesthetists focuses on the principles such as non-malfeasance, beneficence, and patient safety (ASA, 2014). The care team of anesthesiologists and nurse anesthetists works closely to deliver safe anesthetic care to patients during surgery (ASA, 2014). The head of the group is the anesthesiologist, while nurse anesthetists are the most abundant in the hospital setting, providing most anesthetic delivery and patient care (ASA, 2014). The team's responsibility is to assess the patient, develop a plan of care for anesthetic delivery, and support the patient's well-being (ASA, 2014). In addition, it takes careful consideration to determine each patient's course of action due to the risks of surgery (ASA, 2014).

An educational program is an organizational experience that allows for growth and development while also leading towards a defined program objective (May et al. 2018).

Simulation as an educational technique is used to assess competency, promote team training, and has been applied to nurse anesthesia as a tool to decrease human error (Cannon-Diehl et al. 2012). Simulations are imperative when speaking about the education of nurse anesthetists and allow control of potential life-threatening situations that engulf the participants in real-life scenarios (Cannon-Diehl et al. 2012). This allows the participants to think in the moment during a “simulated” experience so that they will be better prepared if said situation arises in real life (Cannon-Diehl et al. 2012).

A safety threat is defined as a plausible threat that can cause serious harm as a result of an intentional or accidental mishap (SDM, 2021).

Conceptual Model

Reason's (2000) Human Error: Models and Management theory is used in this project to frame the construction of a simulation-based educational activity regarding the safe use of anesthesia workstations. The model explores the connection between the person and the system when evaluating safety and quality. The person approach looks at the individual at fault, assuming that they are either forgetful, inattentive, or morally weak (Reason, 2000). The systems approach looks at the environment in which the individual works assume that they are inherently susceptible to making mistakes and that defenses should be built around them to prevent this (Reason, 2000).

The anesthesia workstation safety mechanisms have evolved to coincide with this human error model (Reason, 2000). Each specific safety mechanism on the anesthesia workstation has been designed to counter human errors that caused patient harm. One clinical example of this is the fail-safe mechanisms that prevent providers from delivering pure nitrous oxide (N_2O) without supplemental oxygen (O_2). When nitrous oxide is delivered without enough supplemental oxygen, the patient is subjected to a hypoxic mixture (<21% oxygen), leading to serious patient harm.

The Reason model (2000) notes that blame can be placed on the anesthesia provider to be incompetent and negligent in delivering a hypoxic mixture to the patient. Alternatively, the model recommends a systems approach: the workstation should not be capable of delivering this dangerous hypoxic mixture in the first place. In looking at the Swiss cheese model, illustrating Reason's (2000) perspectives, the anesthesia workstation is layered to prevent provider error and eliminate error from reaching patients. Defensive barriers are engineered into the workstation like the fail-safe mechanism mentioned above. They also include visual and auditory alarms, physical barriers, and automatic shutdowns (Reason, 2000). At the same time, patients and health care providers rely on anesthesia providers to interpret situations and act based on their knowledge and experience. These defenses are implemented strategically, but holes (Swiss cheese model) in these defensive layers can come from two reasons: operational failures and latent conditions (Reason, 2000). The operational failures are unsafe actions committed by anesthetists operating anesthesia workstations, while the latent conditions are dangerous engineering principles or designs provided by the anesthesia workstation manufacturers. When both barriers are breached, the result places the patient at risk for harm.

Review of Literature

Search Strategy

The project directors (PD) started our review of the literature by using the terms: Anesthesia machine malfunction and anesthesia machine. We then expanded our search to more specific areas of the anesthesia machine, including the search terms: pipeline failure, O2 supply line, soda lime, carbon dioxide absorbent canister, APL valve, CO2 simple line disconnect, unidirectional valve malfunction, anesthesia scavenger disconnect, scavenger system, anesthesia bellows housing, GE, Drager, Aysis, Fabius, Narkomed, oxygen sensors failure, chain link 25, anesthesia vaporizer malfunction, simulation-based educational activity, Nurse Anesthetists, patient safety, novice nurse anesthetists, anesthesia workstation, learning exercise, and teaching plans. In addition, we gathered articles that include case reports, summaries, and clinical studies that will support our reasoning behind our DNP project design throughout our search, which can be found in *Table 1*. Due to the topic, there will be no experimental design studies. Studies are observational or descriptive presenting patient case reports from claim databases.

Databases searched: PUBMED; CINHAL

Years searched: 1983 – 2021

Empirical (Research) Literature

Cooper (1984) performed a critical incident analysis to determine the causes of patient harm related to the anesthesia workstation (human vs. mechanical error). A total of 1089 incidents were analyzed (Cooper, 1984). The method of data collection was a retrospective survey as well as subsequently reported incidence after interviews (Cooper, 1984). There were also incidents reported during the introductory interviews with the "trained observers" (Cooper, 1984). The essential information collected was related to human error during the delivery of anesthesia (Cooper, 1984).

The study found that patients with more co-morbidities have more adverse outcomes than those that were deemed healthier (Cooper, 1984). The majority of findings showed that most machine malfunctions were able to be determined with a simple anesthesia workstation check. Human error played a significant role in the determination of patient outcomes as well as machine malfunction (Cooper, 1984). The limitations of the study are related to the many potential ways to define incident types (Cooper, 1984). The retrospective approach and an instant report of the incidents and outcomes all involved unique incidents, which create difficulty when categorizing reports (Cooper, 1984). The implications for practice and research are related to a need for further education, awareness, and vigilance (Cooper, 1984). More education is required as a preventive measure regarding the anesthesia machine and the possible malfunctions resulting in patient injury (Cooper, 1984).

Joyal (2012) showcased a case in which the anesthesia workstation scavenging system became occluded with a small piece of plastic that would allow the anesthesia workstation to be functional and pass self-tests, but also expose a patient to high peak pressures. The anesthesia workstation that was evaluated and used was eventually replaced, and the patient did not suffer any harm (Joyal, 2012). Upon investigation, a small piece of plastic was causing occlusion between the anesthesia workstation and the scavenging system (Joyal, 2012). Limitations to this demonstration was the small sample size and no further demonstrations were completed (Joyal, 2012).

Kee et al. (2006) presented a case report of an inadvertent vaporizer selection malfunction on the North American Drager Narkomed 2C. The purpose of this article was to illustrate a potential safety threat in which both the Sevoflurane (Ultane) and Desflurane (Suprane) vaporizers were simultaneously activated (Kee et al., 2006). After the induction of general anesthetic with an endotracheal tube, an anesthesia provider was able to turn on multiple anesthetic vaporizers at the same time (Kee et al., 2006). This should not be possible as all modern anesthesia workstations have an interlock mechanism which prevents this safety malfunction from happening. In this case the provider was able to quickly notice the malfunction and was able to avoid causing patient harm (Kee et al., 2006). This could have been detected and resolved prior to the induction of anesthesia if the responsible anesthesia provider had followed the ASA’s (2008) recommended pre-anesthesia workstation checklist.

Lateef’s (2010) literature review article discussed the importance and pertinence of simulation-based learning and how it applies to the medical field. It takes an entire team to be dedicated to the purpose of immersing themselves in a simulation-based scenario. Creating a safe simulation area allows the user to explore and expand on their knowledge of complicated situations that may arise within their practice (Lateef, 2010).

The addition of simulation-based training to the field of medicine builds morale and cohesiveness (Lateef, 2010). These practices are designed to be the building blocks of algorithms and protocols that guide healthcare practice (Lateef, 2010). First and foremost, the patient in a simulation is never harmed, hoping that the simulation training would be beneficial when something happens in a real-life situation (Lateef, 2010).

Lee et al. (2013) discussed the integrity and proper positioning of both the inspiratory and expiratory unidirectional valves that are within the anesthesia workstation. The first case reported describes an incident in which an expiratory unidirectional valve breakage resulted in high end-tidal CO_2 up to 52 mmHg, and the inspiratory CO_2 went to 30 mmHg (Lee et al. 2013). The valve was replaced, and the case went on without any other issues (Lee et al. 2013). The patient was not harmed, but the immediate differential diagnosis was to rule out a deadly anesthesia reaction known as malignant hyperthermia, which poses a significant patient safety threat if misdiagnosed or mistreated (Lee et al. 2013).

The second case report was regarding the malposition of the unidirectional expiratory valve. This resulted in end-tidal CO_2 elevation and subsequent sloping of the capnography waveform. Again, the patient suffered no harm, but the machine properly passed its self-test and was not detected.

A closed claims report by Mehta et al. (2013), reviewed the Closed Claims Project database of 9,806 incidents related to anesthesia workstation malfunctions. This Institutional Review Board approved report had inclusion criteria for the cases were that they were general surgery cases and/or obstetric anesthesia care cases (n=6,022) (Mehta et al. 2013). The period in which this study took place was from the 1970s to the 2000s (Mehta et al. 2013). The studies were compared by chi-square tests, Fisher exact test, and Mann Whitney U test (Mehta et al. 2013).

The study concluded that closed claim gas delivery cases decreased over those years due to advancements in technology (Mehta et al. 2013). However, provider error contributed significantly to severe injury and the misdiagnosis or treatment of breathing circuit events (Mehta et al. 2013).

The case report by Mohanty (2018) spoke about the pin index safety system that is used internationally to protect patients from receiving hypoxic mixtures, carbon dioxide, helium, or any combination of those that would be deemed detrimental. During this general anesthesia case, it was found that an old carbon dioxide tank with a faulty pin index system was attached to the oxygen hanger yoke on the back of the anesthesia workstation (Mohanty, 2018). The patient did have a period of desaturation before the problem was recognized and fixed (Mohanty, 2018). Once fixed, the case continued without issue and an oxygen tank was used appropriately (Mohanty, 2018).

The argument for this case report took place in India, where they do not abide by the standard colorization as the United States does (Mohanty, 2018). The call for color-coding was the purpose of this case and the informative matter of connecting a mistaken tank to the hanger yoke on the back of the anesthesia workstation (Mohanty, 2018).

In a case report, Pai (2021) discussed the malposition and improper seating of a CO_2 canister absorbent on the Drager Apollo machine. This resulted in the inability of the machine to develop positive pressure during ventilation even though the machine had passed its self-test (Pai, 2021).

No patient harm resulted from this experience, but the onus is placed on the anesthesia provider to properly check the anesthesia workstation even further than simply doing a anesthesia workstation self-test (Pai, 2021). Since the CO_2 absorbent is a removable portion of the anesthesia workstation, a proper inspection and seating of the canister is required to drive positive ventilation pressure to the patient during general anesthesia (Pai, 2021). Therefore, this requires an additional safety check in order to oblige with the standardized ASA safety standards (Pai, 2021).

A case report by Pauling (2017) regarding the crossing of pipelines within a hospital resulted in the death of a patient that had received 100% nitrous oxide during general anesthesia. This case report discusses and poses the risks associated with delivering a hypoxic mixture to patients during general anesthesia (Pauling, 2017).

The outcome of the case resulted in a patient's death (Pauling, 2017). The inspection into the case revealed that the maintenance team mistakenly crossed the pipelines (Pauling, 2017). Further vigilance is required during general anesthesia as these risks are still posed today due to the maintenance required throughout hospitals (Pauling, 2017).

Saied (2012), created a simulation-based educational activity to teach anesthesia providers the risk related to the loosening of the bellows cap on various anesthesia workstations. Through this simulation-based educational activity providers developed interpersonal skills as well as the skills to recognize and address that the bellows caps was loosened (Saied, 2012). Subsequently, the anesthesia workstation would not be able to drive positive pressure during general anesthesia and would result in apnea, hypercarbia, and possibly death if the leak source was not found (Saied, 2012). From that experience, this tool was developed to allow students to experience a safe environment without the risk of patient harm (Saied, 2012).

Tharp’s (2016) case report discussed the successful management of an anesthesia workstation failure with the Dräger Apollo (Draeger Inc). Approximately 45 minutes into this case, while the patient was under general anesthesia and mechanical ventilation, the anesthesia workstation failed to achieve positive pressurization following a high-pressure alarm (Tharp, 2016). Despite multiple maneuvers, the issue did not resolve until the machine was manually powered off and on at the main power switch (Tharp, 2016).

This case exemplified the importance of having backup ventilation to ventilate a patient when an anesthesia workstation fails (Tharp, 2016). Proper vigilance is needed to ensure that the patient does not sustain any harm (Tharp, 2016). This was a near miss experience and the problem was recognized and reconciled without patient harm (Tharp, 2016).

Theoretical Literature

The ASA Committee on equipment and facilities task force formulated evidence-based recommendations for pre-anesthesia workstation checkouts to be performed both daily and before each anesthetic. These checkout procedures improve patient safety and reduce the risk for anesthesia workstation malfunctions or mishaps. As a result, they are widely accepted and utilized within the anesthesia community.

Oster and Braaten (2016) created a handbook to serve as a patient safety and quality resource for healthcare students and providers. The handbook explains safety concepts within a framework illuminated by examples of applications to practice and consideration across a wide variety of patients. The patient safety and quality resources by Oster and Braaten (2016) provide a didactic framework for learners to form an informative foundation. Allowing learners to more effectively utilize active learning methods such as simulation-based education (Oster and Braaten, 2016).

Related Literature

Subrahmanyam's (2013) review article provided a detailed description of the anesthesia workstations' safety features, mechanics, and reasoning. In addition, it shows possible malfunctions and the potential risks associated with utilizing the anesthesia workstation. As a result, there is an increased emphasis on the importance of vigilance in the delivery of anesthetics. As well as an emphasis on the importance of performing adequate pre-surgical checks to ensure that patient safety is not compromised.

Chiu et al. (2012) performed an experimental research study to test whether a simulation training session would improve junior residents' ability to perform a anesthesia workstation check beyond the level of final year residents who only received didactic training. Experimental anesthesia workstation training sessions were introduced to postgraduate year 1 (PGY-1) residents (Chiu et al. 2012). PGY-1 residents performed a simulated anesthesia workstation check to detect ten preset faults (Chiu et al. 2012). The control group was PGY-5 residents who received only didactic training perform the same anesthesia workstation check (Chiu et al. 2012). Data was collected from 37 simulation residents and 27 control residents, and the findings showed that simulation residents had significantly higher checklist scores than the control residents and identified more anesthesia workstation faults (Chiu et al. 2012). Simulation residents repeated the study again in their senior year, and continued to achieve higher checklist scores and identify more anesthesia workstation faults than control residents (Chiu et al. 2012).

Critical Summary

The literature review presents consistencies related to anesthesia workstation malfunctions that support the implementation of a simulation-based educational activity for novice anesthesia providers. Using this simulation-based educational activity, novice anesthesia providers can work through a variety of malfunctions. Each specific anesthesia workstation malfunction has a unique presentation and poses a patient safety threat. These anesthesia workstation malfunctions have been well documented within the literature and have been largely attributed to human error. To combat these looming patient safety threats, novice anesthesia providers must understand the importance of maintaining astute vigilance to detect and correct any errors before they result in patient harm. The literature review shows the commonality between case reports, studies, and their relationship with proper education, technique, and vigilance of an anesthesia provider. For example, Joyal (2012) showcases an anesthesia workstation malfunction related to a faulty scavenger system. While Kee et al. (2006) showcased a malfunction that allowed two anesthesia workstation vaporizers to be turned on simultaneously posing a different patient safety threat. Although these two cases pose two completely different patient safety threats, the commonality amongst these cases are that the anesthesia providers would have been able to detect and amend these issues if they had performed the ASA recommended pre-anesthesia workstation checkout.

Additionally, Pauling et al. (2017) presented a case study that revealed the dangers of a pipeline crossover that resulted in the death of a patient who received 100% nitrous oxide (N_20). The mistake was only discovered after the incident happened and it was the result of the a stripped internal connection of the N_20. This is a fault in the diameter index safety system (DISS) (Pauling et al. 2017).

Mohanty and Ahmad's (2018) case study reiterates this theme. In this case there was a misleading gas cylinder color coding system which almost resulted in serious patient harm. During an endoscopic sinus surgery under general anesthesia there was a drop in central pipeline pressure. When the O_2 E-cylinder was opened it was found to be empty. Immediately thereafter an attempt to mount another O_2 E-cylinder to the hanger yoke was made, but it did not fit into the pin index safety system (PISS). A third E-cylinder was finally installed and the patient was provided with O_2. The second O2 E-cylinder was actually found to be a CO_2 cylinder that had the same body color as a typical O_2 cylinder. The presence of the PISS was able to prevent serious patient harm in this case (Mohanty & Ahmad, 2018).

In a case study by Robards & Corda (2010), a hazard involving the gas sampling line and adjustable pressure limiting (APL) valve on the Drager Apollo anesthesia workstation was revealed. After the induction of general anesthesia with an endotracheal tube, ventilation could not be achieved despite complete closure of the APL valve in the manual setting of the anesthesia workstation. After extubating and reintubating the patient the anesthesia providers still could not ventilate the patient and had to resort to an AMBU bag as a secondary source of ventilation. In this instance the gas sample line had become wedged between the APL valve knob and the anesthesia workstation surface, creating a significant air leak despite maximal closure of the APL valve. Simply pulling the valve knob upwards and removing the sampling line from the APL valve solved this problem (Robards & Corda, 2010).

Lee et al. (2013) presented a case study that was able to bypass the ASA checklist. A patient was brought to the operating room and induced with no initial problems revealed. Shortly after the case started the end-tidal CO_2 ($ETCO_2$) levels rose. This immediately gave suspicion of malignant hyperthermia due to an elevated $ETCO_2$ being one of the hallmark signs. Upon inspection, it was found that the unidirectional valve on the expiratory side of the anesthesia workstation was broken (Lee et al. 2013).

The common themes in the literature are consistent human error despite design improvements in the anesthesia workstation, component failures, design flaws, and machine malfunctions/engineering failures. These themes are consistent amongst the supporting cases and are important takeaways for novice anesthesia providers to gather from this educational process improvement program. This project is aimed toward confirming this safety through rigorous research and literature reviews.

Theoretical Framework

The Adult Learning Theory by Malcom Knowles (1978) supports the use of simulation as an effective modality for adult learners. The Adult Learning Theory makes four assumptions about the characteristics of an adult learner that are different from the assumptions about child learners (Knowles, 1978). These four assumptions are that adults must be involved in the planning and evaluation of their instruction; that experience (including mistakes) provides a basis for the learning activities; that adults are most interested in learning subjects with immediate relevance and impact on their job or personal life; and that adult learning is problem-centered rather than content-oriented (Knowles, 1978). As the novice anesthesia providers participating in this simulation-based educational activity are adult learners, Knowles' theory serves as a valuable framework for this project.

Method

Design

The design of this project is an educational process improvement program. This is the first phase of this project and includes a literature review with a directed content analysis to identify content for this simulation activity. It also includes the expert review to validate this content.

Sample and Setting

The setting for the development of the project is FJTSA. The first part of the project uses the literature as the source of the data to be analyzed. The second part of the project uses an expert validation. This expert validation will be performed by experienced CRNA’s and anesthesiologists preferably with precepting and/or education experience. Ten to twelve experts will be invited with hopes of having six to eight completed data review forms.

The design will help to facilitate the pre-existing educational growth of novice anesthesia providers. This project will continue to be developed by proceeding DNP cohorts at FJTSA. Additionally, this project has the potential use for new hire orientation programs related to types of anesthesia workstations in use and perhaps safety competency training of CRNAs already in practice.

Ethical Considerations

Institutional review board (IRB) approval will be evaluated once this project is proposed and defended.

Procedures for Data Collection

The data collection for this project consists of the directed content analysis from the review of the literature and the expert review of data collected to validate the content of the simulation tool. The project objectives utilized focus on improving patient safety, enhancing participant confidence, and improving anesthesia provider workstation competence.

Plans for Data Analysis

The directed content analysis approach described by Hsieh and Shannon (2005) will be used to examine the literature for relevant content to include in this educational process improvement program. This directed qualitative content analysis method will serve as a reliable, transparent, and comprehensive method for qualitative research (Abdolghader, et al. 2018). This project will provide quantitative and qualitative data from the expert reviewers.

Implementation

The purpose of this project was to create an educational process improvement program to standardize the education of novice anesthesia providers to prevent safety threats related to the anesthesia delivery workstation. This was accomplished by implementing trigger videos that can be could be used as educational content for novice anesthesia providers within anesthesia departments.

Our team met on multiple occasions with experienced anesthesia providers to assess common critical incidents that they have experienced related to the anesthesia workstation throughout their professional career. We solicited the input from experienced anesthesia providers including anesthesiologists and nurse anesthetists. These anecdotal qualitative interviews were conducted with experienced anesthesia providers and assisted us in selecting five key scenario topics.

The time spent on the development of our trigger films and educational platform is as follows: Twelve hours were spent polling and reviewing this information. Six hours were spent developing scripts. Six hours were spent meeting with film technicians preparing for our filming day. Six hours were spent filming trigger films. Six hours were spent meeting with a simulation lab technician in the editing room identifying the key professional teaching points associated with each trigger film.

Plan of Implementation

Action	Team	Hours
Soliciting Feedback from Experienced Anesthesia Providers	Robert Vitale, James Mahon, and anesthesia providers	12 hours.
Identifying core team for trigger film production	Robert Vitale, James Mahon, Michael Kost, and Audrianna Bustos	6 hours
Drill down on scripting	Robert Vitale, James Mahon, and Michael Kost	10 hours
Filming trigger films	Robert Vitale, James Mahon, Michael Kost, and Audrianna Bustos	6 hours
Editing trigger films	Robert Vitale, James Mahon, Michael Kost, and Matt White.	6 hours
Incorporation of trigger films with educational content	Robert Vitale, James Mahon, and Michael Kost.	10 Hours

Discussion

Despite developing this educational platform with novice anesthesia providers in mind, it can be further utilized at anesthesia departmental staff meetings within facilities such as Einstein Medical Center Montgomery or through online narrated educational programs. Barriers of implementation include the dissemination of this educational platform within anesthesia departments to their target audience. The decision to make this a mandatory competency requiring 100% compliance will be at the discretion of the anesthesia department that wishes to implement this educational platform.

Project Committee

Chair: Dr. Michael Kost

Mentor: Dr. Barbara Hoerst/ Dr. Deborah Byrne

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Appendix

Table 1

Search Process Review of Literature

N=119					
Database	**Total Articles**	**Articles Remaining After Title Review**	**Articles Remaining After Abstract Review**	**Articles Retrieved and Examined**	**Articles that fit Inclusion Criteria**
PubMed	**87**	**66**	**59**	36	27
CINAHL	**32**	**20**	**10**	**7**	**6**
Total	**119**	**86**	**69**	**43**	**33**

Note. **Number of duplicate articles removed - 12**

Table 2

Review of Literature Matrix

Database # Article First Author, Year (full citation in References)	**Purpose of Study Major Variables (IV, DV) or Phenomenon**	**Theory or Conceptual Framework**	**Design**	**Measurement Major Variables (Instrument)**	**Data Analysis (Name of Statistics, descriptive, Inferential and Results)**	**Findings**	**Evidence Level of Research & Quality Johns Hopkins Nursing Evidence-Based Practice**

CINAHL #1 Cooper, 1984	Determination of causes for patient harm related to anesthesia workstation human vs mechanical error.	N/A	Retrospective/Instant reporting. Non-experimental observational descriptive report. N - 1089 (616 - retrospective; 239 subsequent incident reports; additional 234 incidents were reported by trained observers.	Anesthesia provider Questionnaire/Interview	The results concluded that 234 incidents were reported in the directed interviews. There were 70 incidents with substantive negative outcomes. The remaining	Less healthy patients are at a higher risk than healthier patients. Also, mishaps should be categorized based on preventative measures rather than outcomes.	Level 3 Quality B

					164 were near misses and did not result in negative outcomes.		
CINAHL #2 Joyal, 2012	Determination of whether anesthesia workstations will pass a machine checkout with	N/A	Simple demonstration	N/A	N/A	Scavenging issues will go undetected if covered by plastic.	Level 3 Quality C

	a scavenger malfunction.						
CINAHL #3 Kee, 2006	Case report of an inadvertent vaporizer selection malfunction on the North American Drager Narkomed 2C. Sevoflurane and	N/A	Case report	N/A	N/A	First documented failure of this anesthesia workstation type. Case report to educate and inform.	Level 3 Quality C

	desflurane vaporizers were simultaneously activated.						
PUBMED #1 Lateef, 2010	The purpose of this article is to evaluate a simulation-based educational activity to enhance performance	N/A	N/A	N/A	N/A	simulation-based educational activities have opened up a new educational opportunity within the medical	Level 3 Quality C

	and reduce errors.					community. They recommend that the cost effectiveness of simulation-based learning compared to improvements in clinical competence and its impacts on patient safety	

						be further evaluated.	
PUBMED #2 Lee, 2013	The purpose of this article is to evaluate malfunctions that can occur within the unidirectional valve of the anesthesia machine and the patient safety risks these	N/A	Case Study	N/A	N/A	Two case reports experienced a breakage in a unidirectional valve resulting in sudden increases in ETCO2 readings and PiCO2 readings after	Level 3 Quality C

	malfunctions carry.					about 10 minutes of general anesthesia. The problems were eventually diagnosed and neither scenario resulted in patient harm.	
PUBMED #3	Evaluation of the closed claims cases	N/A	Retrospective. Case report evaluations.	Closed claims project database	The results concluded that	Gas delivery equipment claims in the	Level 3

Mehta, 2013	of gas delivery systems between the 1970s and 2000s.		Non-Experimental observational.		anesthesia gas delivery claims decreased over the decades (P < 0.001) to 1% of claims in the 2000s. The claims that were cited from 1990 to 2011 (n=40) were less severe and had a	Closed. Claims Project database showed a decrease in 1990-2011 when compared with earlier decades.	Quality A

					greater proportion of awareness (n=9, 23%; P= 0.003) and pneumothorax (n=7, 18%; P= 0.047). The majority of claims examined were related to provider error with (n=7) or		

					without (n=27) equipment failure. Thirty-five percent of claims were judged as preventable by pre-anesthesia machine checks.		

PUBMED #4 Mohanty, 2018	To prompt recognition and immediate intervention of a case report involving an erroneous carbon-dioxide cylinder color coding which was mistaken	N/A	Case Study	N/A	N/A	During a general anesthesia procedure there was a drop in central pipeline pressure requiring E-type oxygen cylinders to be utilized. The already mounted oxygen	Level 3 Quality C

	as an oxygen cylinder.					cylinder was empty requiring a change. But when the new oxygen cylinder was unable to be attached it was discovered that the oxygen cylinder was actually an E-type carbon	

						dioxide cylinder with a nearly similar color coding as an oxygen cylinder but a different pin index safety system.	
PUBMED #5	A case report discussing the malposition and improper seating of a	N/A	Case report	N/A	N/A	No patient harm resulted from this experience, but the onus	Level 3 Quality B

Pai, 2021	CO2 canister absorbent on the Drager Apollo machine. This resulted in the inability of the machine to develop positive pressure during ventilation even though the machine had passed its					is placed on the anesthesia provider to properly check the anesthesia machine even further than what the self-test will do. Since the CO2 absorbent is a removable portion of the anesthesia, a	

	self-evaluation test.					proper inspection and seating of the canister is required to drive positive ventilation pressure to the patient during general anesthesia.	
PUBMED #6	To discuss and pose the risks that are	N/A	Case Report	N/A	N/A	The outcome of the case was a patient	Level 3 Quality C

Pauling, 2017	associated with the ability to deliver a hypoxic mixture to patients during general anesthesia.					death. The inspection into the case revealed that the maintenance team that performed the work on the pipelines crossed them mistakenly. Further vigilance is required during	

						general anesthesia as these risks are still posed today due to the maintenance that is required throughout hospitals.	
PUBMED #7	To create a simulation-based educational	N/A	Simulation-based educational activity	Guided study questions.	N/A	That there is a need for further education	Level 3 Quality B

Saied, 2012	activity to teach novice anesthesia and experienced anesthesia providers the risk of the bellows cap on any anesthesia workstation that allows the cap of the bellows to be loosened.					related to the development of interpersonal skills as well as the recognition that the bellows cap can be loosened. Subsequently, the anesthesia machine would not be able to drive	

						positive pressure into the patient during general anesthesia and would result in apnea, hypercarbia, and possibly death if the source of the leak was not found. From that	

						experience, this tool was developed to allow students the experience in a safe environment without the risk of patient harm.	
PUBMED #8	To examine successful management of an	N/A	Case Study	N/A	N/A	This case report emphasizes the	Level 3

Tharp, 2016	anesthesia machine failure with the Draeger (or Dräger) Apollo (Draeger Inc) anesthesia workstation					importance of always having a backup means of patient ventilation and anesthesia administratio n.	Quality C

Appendix B

Simulation-Based Educational Activity for Novice Anesthesia Providers Learning Safe Management of The Anesthesia Workstation					
Content Experts: Please critique parts of the draft of James Mahon and Robert Vitale. Please read each section and rank the sections using the scale provided. Use yellow highlighting to select the number on the scale, save the document, and email to Jamesmahon@live.com and RV676096@gmail.com. Thank you very much. Circle your responses on the 4-point scale provided. Kindly comment on additions, deletions, and revisions as you evaluate each section.					
1. The simulation activity presents possible realistic workstation malfunctions.	1 = not relevant	2 = unable to assess relevance without item revision or item in need of such revision that it would no longer be relevant	3 = relevant but needs minor alteration	4 = very relevant and succinct	Comment
2. The simulation activity presents a malfunction that can be identified by provider.	1 = not relevant	2 = unable to assess relevance without item revision or item in need of such revision that it would no longer be relevant	3 = relevant but needs minor alteration	4 = very relevant and succinct	Comment
3.	1 = not relevant	2 = unable to assess relevance	3 = relevant but needs	4 = very relevant and succinct	Comment

		without item revision or item in need of such revision that it would no longer be relevant	minor alteration		
4.	1 = not relevant	2 = unable to assess relevance without item revision or item in need of such revision that it would no longer be relevant	3 = relevant but needs minor alteration	4 = very relevant and succinct	Comment