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Improving the Knowledge of Anesthesia Providers on Preventing and Managing Intraoperative Anesthesia Machine Failure

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Improving the Knowledge of Anesthesia Providers on Preventing and Managing Intraoperative Anesthesia Machine Failure

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ABSTRACT

Background: The anesthesia machine is important medical equipment in the operating room that provides safe anesthesia delivery to patients. Despite improvement from a mechanical to a computerized electronic device, on rare occasions, the anesthesia equipment system can fail. The anesthesia machine delivers oxygen and anesthetic gas to patients during surgical procedures. Breathing circuit leaks or failure during surgical cases have been reported to the Food and Drug Administration (FDA). Injury resulted from anesthesia equipment malfunction can be detrimental to patient outcome. The objective of this quality improvement project is to improve the knowledge of anesthesia providers on preventing and managing intraoperative anesthesia machine failure.

Methods: An extensive database search that included Cumulative Index to Nursing and Allied Health Literature (CINAHL), PubMed, Medline, the National Center for Biotechnology Information (NCBI), and Google Scholar was used to searching for articles relevant to preoperative anesthesia machine failure.

Results: The 6 articles selected for this literature review focused on analyzing anesthesia machine faults, identifying errors and equipment failure, and educating or training providers on addressing anesthesia machine failure.

Keywords: Anesthesia machine, anesthesia system delivery failure, anesthesia apparatus malfunction, perioperative anesthesia machine failure, prevention and management, complications, equipment problems, breathing circuit failure.

INTRODUCTION

Problem Identification

The anesthesia machine is considered one of the most critical medical devices anesthesia providers use to deliver anesthetic agents to surgical patients safely.[1] The knowledge and skills of the anesthesia providers are crucial to manoeuver the anesthesia workstation. The anesthesia machine delivers oxygen and other specific anesthetic gases concentrations to patients through the breathing system.[1] The anesthesia apparatus has been modified gradually from a simple device to a mechanical, electrical, and computerized device to improve patient safety and facilitate its usage by the provider. Since its invention in 1846 by Morton, anesthesia has been delivered to patients without a machine. However, oxygen and nitrous oxide were introduced in anesthesia in the late 19th century. Boyle modified Gwathmey's machine in 1917 to provide anesthesia.[1]The complex composition of the modern anesthesia machine originates from the Boyle anesthesia machine.

The basic structure of the anesthesia machine remains the same despite updates and improvements made over the years. The changes are intended to improve patient safety, but the recurrence of mechanical faults such as a leak, obstructions, or new gadget malfunction may occur with modern machines. There is no perfect satisfactory checklist applicable to all anesthesia machines when assessing the device's proper function.[2] The device may be prone to malfunction due to human errors and the complexity of its components. Human errors continue to be a significant cause of anesthesia-related mortality and morbidity. Failure to perform pre-anesthesia equipment checks is common in anesthesia system failure.[3] In 1987, the Food and Drug Administration (FDA), the American Society of Anesthesiologists (ASA), and the anesthesia machine manufacturers collaborated to develop the anesthesia apparatus checkout

recommendations.[3] When evaluating the efficacy of the anesthesia machine checklist, one research study shows that providers detected only 30% of machine failures with or without using the FDA checklist.[3] Practitioners must possess a thorough knowledge of the anesthesia machine's proper function to prevent intraoperative machine failure detrimental to patient outcomes.

Background

There have been cases where failed bag-ventilator switch in anesthesia machines have caused a large breathing-circuit leak. The failure was caused by a cracked toggle actuator of the switch that was not visible. While performing a thoracotomy with one-lung ventilation, the patient had to be manually ventilated due to hypoxia. The particular anesthesia apparatus developed a major leak during the case and failed to deliver positive pressure either on ventilator mode or bag mode. The leak could not be identified when troubleshooting the machine during the event. The patient was disconnected from the breathing circuit, and ventilation continued manually. After the case, the machine was inspected and found that the leak resulted from the internal bag-ventilator switch toggle actuator fracture. The machine functioned adequately after, and the defective component was replaced.

As the trauma patient arrived in the operation room, the pre-anesthesia recommended checkout was performed on the machine. The anesthesia machine ascending bellows were not fully returning to the prior end-exhalation position. The bellows continued to lose volume despite adequate fresh gas flow. No leak was detected when switching from the bag-ventilator mode to bag; however, a large leak was detected when the machine was switched to ventilator mode. After inspecting the anesthesia machine, a buildup of viscous substance was noticed on the internal aspect of the selector switch that prevented the full engagement of the switch to ventilator mode position and prevented the bellow from expanding fully.

Another anesthesia machine circuit leak was reported to the FDA during a total abdominal hysterectomy. The exhaled tidal volume decreased after initiating positive pressure ventilation. The patient had to be manually ventilated because of the loss of tidal volume even when increasing the set tidal volume and increasing the fresh gas flow to 8 L/min. The leak originated from a pneumatic connection between the mechanical and manual ventilation circuits. There was a crack in the internal plastic of the bag-ventilator selector switch. The defect was resolved once the internal plastic housing was replaced and the machine functioned normally.

With the possibility of anesthesia workstation malfunction preoperatively, anesthesia providers must always be prepared to utilize an alternative ventilation method. The pre-anesthesia equipment checkout does not guarantee the proper functioning of devices; hence, it is crucial to have backup ventilation equipment available. A practitioner's inability to detect a breathing circuit failure may lead to health complications and poor patient outcomes. The anesthesia providers must be able to recognize when equipment fails to operate safely. Suppose the apparatus failure is not recognized promptly by the provider. In that case, it may lead to excessive gas concentrations delivery or lack of adequate anesthesia depth, awareness, respiratory failure, and patient injury.[4] Therefore, for the benefit of quality patient outcomes, the anesthesia practitioner needs to be knowledgeable in identifying and managing equipment malfunction to minimize the possibility of patient injury or adverse events

Scope of the Problem

The breathing circuit leak in the reported anesthesia machine was large but invisible and difficult to detect due to its location within the machine. Intraoperative anesthesia equipment faults are one of the causes of anesthetic morbidity. The occurrence of faulty components in anesthesia machines is rare but can harm patient outcomes. A retrospective research study

conducted in 2002 on equipment failure during anesthesia concluded that out of 83,154 anesthetic cases, only 0.05% of regional cases and 0.23% of general cases were related to equipment problems.[5] Due to human error, the anesthesia machine malfunction only constituted one-third of the problems reported, and there was no morbidity or mortality related to the failure.[4] The researchers concluded that the rate, frequency, and severity of anesthesia equipment failure was low; however, faulty equipment records were analyzed to propose measures to prevent failures.[5]

A retrospective research study conducted by Fasting and Gisvold in 2002 on equipment problems during anesthesia found that the anesthesia machine, including the breathing system as the most common cause of equipment problems.[5] The anesthesia machine and the breathing system constituted about 31% of equipment problems, and other prior research studies have shown similar results.[5] The most common problem related to the anesthesia machine is the breathing system because this component is often cleaned, replaced, disconnected, and reconnected. Fasting and Gisvold research study found that human error and misuse of anesthesia equipment were common causes of equipment failure.[5]

Although intraoperative equipment failure is rare when it happens, if not resolved on time or if the providers are not adequately prepared, the failure may result in patient death. Anesthesia machine breathing-circuit leak can deprive patients of adequate depth of anesthesia and contribute to anesthesia awareness. The ability of the practitioners to prevent, detect, and manage circuit leaks on time is crucial to avoid patient injury due to respiratory complications and lack of adequate anesthesia depth during surgery. Anesthesia providers' lack of knowledge on anesthesia apparatus proper function may result in poor anesthesia management leading to compromising patient status such as respiratory and cardiovascular failure.

Consequences of the Problem

A properly functioning anesthesia machine and breathing circuit are crucial for safe anesthesia delivery. Routine anesthesia machine and circuit leak test must be performed preoperatively following the FDA's recommended anesthesia apparatus check-out recommendations. Even though a preoperative anesthesia check is performed, there is still a possibility of an undetected circuit leak. In the cases of circuit leak reported on anesthesia apparatus failure, a checkout was performed, and the leak was undetected. A negative leak test does not warrant an uneventful intraoperative respiratory circuit leak during the case. A respiratory leak during a case may result in hypoxia, hypoventilation, inadequate gas delivery, light anesthesia, and anesthesia awareness.[6] A small leak can occur in unusual places in the anesthesia machine, such as the capnography sampling line, a fresh gas circuit valve crack, an incorrect installation of a canister or the breathing circuit, or leakage from the junction of two vaporizers.[6] Small leaks can happen anywhere in the anesthesia machine and go undetected by a conventional leak test. When a small leak occurs in the low-pressure system, it may result in hypoxia and awareness.[6]

A breathing circuit leak during general anesthesia may result in inadequate gas delivery. Most research studies attribute awareness to an inadequate level of anesthesia. Anesthesia awareness is when the patient becomes conscious during surgery under general anesthesia.[7] Awareness is a rare incidence, but the patient may experience posttraumatic stress disorder due to the traumatic event.[7] Even though a rare event, in 2016, Sullivan reported that awareness occurred about 1 to 2 times per 1,000 patients, an estimate of 20,000 to 40,000 cases per year.[7] Intraoperative awareness can occur by the anesthesia provider's inattention, anesthesia machine misuse, or malfunction leading to inadequate delivery and depth of anesthesia.[8] Although a rare

incidence, an anesthesia provider's lack of knowledge to adequately prevent and manage anesthesia equipment faults may cause inadequate anesthetic agents delivery and oxygen delivery, resulting in patient injury and even death.

Knowledge Gaps

A German quality assurance project published 3 research studies regarding perioperative incidents in the operating room and recovery room. The frequency of equipment problems was 0.7% in 18,350 cases, 9 0.9% in 26,907 cases, 10 and 1.2% in 96,000 cases.[4] Other research studies by Short and colleagues reported a frequency of 0.23% of equipment/breathing system problems in 16,379 anesthetics, with only 0.76% as the overall problem rate.[9] Spittal and other colleagues reported a 2% incidence of equipment-related problems in 5056 cases with 6.68% as an overall problem rate.[10] The researchers concluded that equipment problems were rare and of low severity and had unwanted effects on patients but did not cause lasting morbidity. Fasting and Gisvold stipulated that these problems did not cause lasting morbidity. However, they can cause serious adverse outcomes, and it is crucial to address anesthesia machine failure with preventative measures.[6]

Human error is a significant factor when estimating anesthetic complications.[3] Several research studies concluded that failure to perform pre-anesthetic equipment checks is associated with anesthesia workstation system failure.[3] It has also been found that only 44% of pre-arranged machine failures are detected through routine equipment check-outs.[3] In 1987, the FDA and the ASA developed and published the "Anesthesia Apparatus Checkout Recommendations" to reduce injury associated with critical anesthesia apparatus.[3] The FDA checklist has been the standard for anesthesia equipment checkout. The checklist was revised in 1994; providers have identified only 30% of anesthesia machine failures with or without the checklist. Since the

revised FDA checklist, no research study has been conducted to confirm its validity in detecting pre-anesthesia equipment failure, including human error.[3] Equipment misuse and human factors such as practitioners' omission of pre-anesthesia equipment check are more common causes of equipment failure.[6]

Proposal Solution

Before administering anesthesia, the FDA apparatus checkout list is recommended to prevent malfunction during surgical cases. The FDA apparatus checklist does not guarantee against intraoperative equipment failure. The provider is responsible for performing equipment checks before anesthesia, preparing to manage the patient airway in the event of an anesthesia machine failure, and avoiding light anesthesia that may result in awareness. Human factors play a significant role in intraoperative machine failures. A 3-level approach is suggested to reduce the possibility of human error.[2] First, design equipment that can minimize human error. Second, if unable to prevent human error, design equipment to minimize patient injury. Third, equipment should include monitors and alarms to alert the provider of changes in the patient's condition resulting from equipment failure.[2]

An educational intervention will equip the providers with the necessary skills to avoid and manage an anesthesia machine failure. In case of a breathing circuit failure with the anesthesia machine, the provider may have to do more than change the bag-ventilator switch from bag to ventilator mode. The anesthesia provider must check the breathing circuit, carbon dioxide absorber, vaporizers, and hoses and ensure that the ventilation mode selector switch has been pushed to its mechanical limit. The toggle actuator or its anchoring mechanism may have failed; therefore, convert to ventilating with an inflating manual resuscitator and providing an alternate means for ventilation, usually with a spare anesthesia machine.[4] It is imperative to have

the defective anesthesia machine evaluated by a qualified service professional before being used in another case. In case of a failed anesthesia machine breathing circuit, it is imperative to access the patient airway and use an inflating mechanical ventilation device to maintain the patient airway.[11]Replacing the anesthesia machine when unable to detect and resolve the breathing circuit leak to prevent the patient from deteriorating due to lack of adequate ventilation or adequate depth of anesthesia.

The focus of the educational intervention is on improving the provider's knowledge on how to prevent and manage anesthesia apparatus in case of failure. The providers will be educated on the necessary measures to avoid and manage a machine failure to minimize the probability of intraoperative anesthesia equipment malfunction that can potentially harm the patient.

Summary of the Literature

In a prospective study by Larson and colleagues, the researchers sought to establish the correlation between anesthesia practice experience of the provider and the ability to detect anesthesia machine faults.[12] The research hypothesis was that more experienced providers should be able to detect anesthesia machine malfunctions. During a national meeting, 87 anesthesia providers were observed performing anesthesia machine checkout procedures. Each volunteer in the research study used the same anesthesia machine, which contained 5 preset faults. The 5 preset faults included an empty oxygen cylinder, a leak in the water trap, a faulty exhalation valve, a dead backup battery, the oxygen and nitrous oxide fail-safe linkage removal, and a source of electricity and pressurized gas. The research comprised 35 participants with over 7 years of experience, 23 participants with 2-7 years of experience, and 29 participants with 0-2 years of experience. All participants' average of faults detection was 3.1, and the results of

detected faults among the group of participants were 3.7 faults for 0 –2 years of experience, 2-7 years averaged 3.6 faults detection, and 7 years of experience practitioners found a mean of 2.3 faults ($p < 0.001$). The research found that insufficient pre-anesthetic check of the anesthesia machine continued to be a recurring human error that caused concerns. The researchers in the study concluded that despite the standardized checklist for anesthesia machine checkout, problems detecting faults in anesthesia workstations were ongoing problems.

While Larson and colleagues study focused on establishing the correlation between the providers experience and the aptitude to detect anesthesia machine failure, the randomized study by Olympio and colleagues sought to determine the anesthesia resident's level of performance and the degree of improvement of the anesthesia workstation checkout procedure after providing the resident's instructional video review on checkout procedure.[13] Clinical anesthesia (CA) residents test group comprised 16 students with 5 students in year 3 training, 6 students in year 2 training, and 5 residents in year 1 training. The control group contained 5, 4, and 4 students, respectively. There was a significant improvement on the checkout procedure. After the intervention, 81% of the criteria were met, 8.3% partially met, and 11% of criteria were not met. Entry-level residents' performance was at a rate equivalent to senior residents. The study did not show that intensive review of checkout procedures would lead to remarkable completion rates. The goal of the research was to improve residents' understanding of the anesthesia apparatus check-out recommendations, but the results did not show overall significant improvement in performance after intensive review instructions. Larson and colleagues found that insufficient pre-anesthesia machine check despite use of standardized checklist continued to be an unresolved issue; moreover, Olympio and colleagues study did not show overall major

improvement in anesthesia residents' performance despite instructional video review on anesthesia apparatus checkout procedure.

Olympio and colleagues sought to evaluate the performance of anesthesia resident's performance for improvement after exposure to an instructional video of the anesthesia machine checkout; on the other hand, the randomized cross-over design research by Blike and Biddle aimed to compare the standard FDA checklist with a highly interactive electronic checklist.[3] A computerized checklist was developed, and two groups of participants consisted of Certified Registered Nurse Anesthetists (CRNAs) and attending anesthesiologists with at least 14 months of postgraduate experience. The machine faults were grouped into easy and difficult tasks. The detection of the difficult tasks was higher when using the electronic checklist versus the FDA checklist. The difficult tasks detection using the electronic checklist was 73%, and the FDA checklist was 38%; however, overall faults detection was lower regardless of the checklist method being used. The researchers confirmed that the electronic checklist improved the detection of pre-anesthesia equipment malfunction at a rate either equal or superior to the FDA checklist. Olympio and colleagues study found insignificant improvement in anesthesia residents' performance after anesthesia workstation video review, in addition, Blike and Biddle's comparison study of the standard FDA machine checklist with the electronic checklist yielded insignificant improvement in overall machine checkout faults detection; besides, the proposed electronic checklist in the study would be expensive to implement.

The focus of the Blike and Biddle study was the comparison of the standard FDA machine checklist with an electronic machine checklist, but Henry conducted a randomized control study in 1989 to examine the efficacy of a pretest and posttest design educational course concerning the detection of anesthesia apparatus malfunction.[14] The research was designed as a

treatment group, and a control group with participants consisted of students in the Nurse Anesthesia Program at the University of Kansas Medical Center.

During the pretest period, there was no difference between the control group and the treatment group. For the posttest, the treatment group showed a significant difference in the number of machine faults detection. The treatment group's mean percentage of detected machine faults in the posttest was 74%, and the control group was 59% detection. As a result, participants exposed to the educational course on detecting anesthesia machine faults had an increased ability to detect faults versus participants who were not exposed to training in anesthesia machine faults detection.

Blike and Biddle's study compared the FDA machine checklists with an electronic interactive checklist, and the overall results in improvement in faults detection were insignificant. In contrast, Olympio and colleagues study found insignificant improvement in anesthesia residents' performance after anesthesia workstation video review while the study by Henry consisted of a pretest and posttest educational course found an increased ability in participants to detect machine failure compared to subjects who did not participate in an educational course to detect machine failure.

The retrospective study analysis by Fasting and Gisvold analyzed the frequency, type, and severity of equipment-related problems in Norway University Hospital of Trondheim anesthesia department.[6] Anesthesia-related data were recorded from all anesthetic cases on a routine basis. The data included intraoperative problems and the severity of the problems. The recorded charts of 83,154 consecutive cases for five years from 1996-2000 were retrieved from the archive for analysis. Most of the equipment problems were insignificant. About 157 cases of anesthetic equipment problems were reviewed. About one-quarter were of intermediate severity,

and 4 were severe problems. All the severe problems and 29 intermediate problems affected the patients, but none of the patients suffered lasting complications. The anesthesia machine constituted one-third of the problems. The most common problem was leakage and misconnection of the breathing system. Human errors were about one-quarter of the equipment problems. Based on the result of the research, equipment problems were rare and the severity was low. Human errors played an important factor in equipment problems.

Mehta and colleagues conducted a retrospective study analysis of patient injuries related 9,806 total claims from the American Society of Anesthesiologists (ASA) closed claims database compared gas delivery equipment injuries between certain periods of time.[15] Eighty percent of claims involved providers' errors with equipment failure. Thirty-five percent of claims were preventable and could be avoided by performing a pre-anesthesia machine check. The research also concluded that gas delivery equipment claims decreased in 1990–2011. Human errors such as inadequate alarms, misdiagnosed breathing circuit events, or improvised oxygen delivery systems contributed to severe patient injuries. While Mehta and colleagues sought to analyze claims related to patients injuries caused by gas delivery system, Fasting and Griswold's study investigated the frequency and severity of anesthetic equipment problems. Both studies found that human errors constituted an important factor in equipment failure.

Methodology of Literature Review

Inclusion Criteria

This literature review included research studies that addressed the objectives set for the review. There are few recent studies on anesthesia machine failure. The search's inclusion criteria comprised research studies published from 1989-2021 in English. Search criteria for this literature review comprised systematic reviews, meta-analyses, and randomized controlled trial

(RCT) studies focused on anesthesia delivery systems management, anesthesia machine failure with abstract and full-text availability. Exclusion criteria included breathing system failure outside anesthesia administration and non-surgical clinical settings.

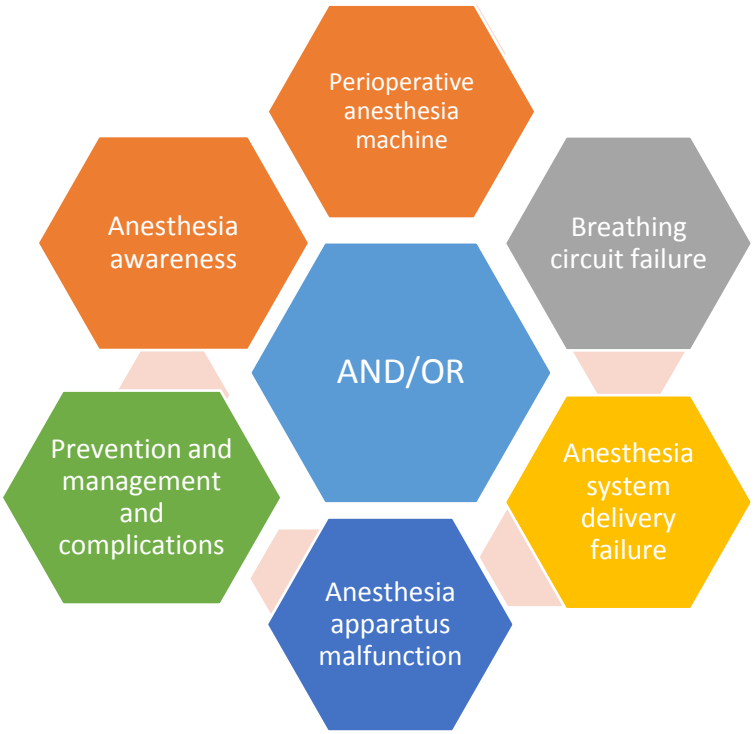
Search Strategy

Databases used for this review were accessed through the Florida International University (FIU) library services such as CINAHL, PubMed, and NCBI search engines. Also, Google Scholar was used to searching for articles relevant to this literature review.

The following search keywords were identified using the appropriate Boolean operators and search symbols: anesthesia machine, anesthesia system delivery failure, anesthesia apparatus malfunction, perioperative anesthesia machine failure, prevention and management, complications, equipment problems, breathing circuit failure.

In the end, a total of 24 articles were selected for full abstract review from both CINAHL and PubMed databases. Twelve articles were analyzed, and 8 articles of the 12 were thoroughly read. Only 6 of the final 8 articles met the research criteria and were chosen for summarization.

Figure 1. Keywords



Study Selection

A comprehensive literature review was conducted using the following search databases: Medline, the National Center for Biotechnology Information (NCBI), PubMed, the Cumulative Index to Nursing and Allied Health Literature (CINAHL) through the FIU library search engine and google scholar from 1989 to 2021. Research related to perioperative anesthesia machine failures causes and consequences were identified, as well as prevention and interventions to improve the knowledge of anesthesia providers in case of anesthesia delivery system failure during surgery.

Through the FIU library system, CINAHL yielded 70 articles, and PubMed yielded 64 articles. After excluding duplicate articles and titles irrelevant to the PICO question, a total of 15 articles from CINAHL and 9 PubMed were selected. Articles from both CINAHL and

PubMed are 24 articles, and 12 articles were reviewed for approval; 8 met the criteria for full reading, and 6 were selected for summarization.

Results of Literature Review

Study Characteristics

The 6 articles selected for this literature review focused on analyzing anesthesia machine faults, identifying errors and equipment failure, and educating or training providers on addressing anesthesia machine failure. One prospective research study by Larson and colleagues in 2007 to identify anesthesia machine faults concluded that anesthesia machine checkout procedures continued to be a problem, and some providers could not detect preset anesthesia machine faults.[12] Two studies were randomized research focusing on evaluating the efficacy and improvement of the anesthesia machine check-out performance. The randomized research study by Blike and Biddle focused on detecting equipment failure.[3] Two retrospective studies analyzed the frequency, type, and severity of equipment-related problems. Lastly, 1 retrospective study on anesthesia delivery equipment improvements and providers' training. The 6 selected articles for this literature review aimed to improve providers' knowledge on preventing and managing intraoperative anesthesia machine failure.

Table 1. Summary of Research Articles

Author(s)	Purpose	Methodology/ Research Design	Intervention(s)/ Measures	Sampling/Setting	Primary Results	Relevant Conclusions
Fasting and Gisvold (2002)	To analyze the frequency, type and severity of equipment-related problems.	Retrospective study analysis Level 1	The study is based on a system in which anesthesia related data are recorded from all anesthetic cases on a routine basis. The data included intraoperative problems and their severity.	From 83,154 anesthetics cases in Norway University Hospital of Trondheim anesthesia department	Of 83,154, the frequency of anesthetic equipment problems was found to be 0.05% during regional anesthesia, and 0.23% during general anesthesia.	When a very low flow of 0.5 L/min is used, volume control is safer than pressure control mode since leak alarms only occurred with 16G hole. However when a flow of 1L/min was used, there was no difference in leak compensation between volume and pressure control modes.
Blike and Biddle (2000)	To perform a critical analysis of the procedure of the revised FDA checklist with adherence to accepted "human factor" design principles	Randomized study Level 1	A randomized cross-over design, anesthesia providers search for prearranged faults over a 2-day period using both the electronic and standard approaches. The electronic checklist was superior to standard practice in the detection of "easy" and "difficult" equipment.	Study subjects *N* = 22 were randomized in to 2 match groups. Four anesthesia apparatus faults sets were randomly generated from a master list of 20 apparatus faults.	Fault detection for each fault except A2-2 using the electronic checklist was either equal to or superior to the detection rate achieved using the FDA checklist	Anesthesia providers missed 30% of the difficult faults presented. The electronic list was better than the FDA checklist. Both checklist was unsuccessful at reducing false negative checks d/t error in operator technique.
Henry (1989)	An educational course concerning the detection of anesthesia machine faults utilizing a standardized anesthesia machine checkout procedure developed by the Food and Drug Administration in association with biomedical engineers, anesthesiologis	Randomized review Level 1	A pretest and posttest design was utilized in order to examine the efficacy of an educational course concerning the detection of anesthesia machine faults utilizing a standardized anesthesia machine checkout procedure developed by the Food and Drug for reducing the commission of human error in anesthesia practice in the form of	Subjects participating in the study were a convenient sample of students in the Nurse Anesthesia Program at the University of Kansas Medical Center. Students were either first, second, or third year master's students in anesthesia education, along with practicing CRNAs who were returning to complete their master's in anesthesia. A total of 35 students participated in the study, and assignment to either the treatment or the	The mean percentage of machine faults detected by the treatment group in the posttest was 74%. The mean percentage of machine faults detected by the control group in the posttest was 59%. Experience in anesthesia practice has been shown to increase the fault detection ability of anesthetists. The level of experience of participants did not affect machine	The majority of morbidity and mortality suffered in relation to anesthesia is due to human error This caveat has been reported and substantiated by past as well as present studies of morbidity and mortality related to anesthesia. In addition, ubstantive proportion of human error committed in anesthesia practice is related to failure to perform an

	ts and industry representatives.		failure to detect anesthesia machine faults.	control group was random.	fault detection (ANCOVA, p = 0.5993).	adequate preoperative check of anesthesia equipment, including the anesthesia machine, failure to perform an adequate preoperative check of anesthesia equipment contributes to human error committed in anesthesia practice, and ultimately, morbidity and mortality has suffered as a result of anesthesia as well.
Olympio et al. (1996)	To determine residents' performance of institutional checkout procedures and the degree of their improvement after instructional video review.	Prospective review Level 1	Differences were sought between the clinical anesthesia (CA) l-, 2-, and 3-yr residents. Percent "perfect," "partial," or "no "completion of each criterion was calculated to determine performance and improvement.	Twenty-nine residents performing a list of pre-use checkout procedures were videotaped (VT11 prior to randomization into a Control or Test group. The Control group had a second videotaping (VT2), whereas the Test group received instructional review of VT1 prior to VT2.	A low-performance rate of 69% (20.61 30) occurred in VTI, significantly improving to 81% (24.2/30) in the Test group after intervention (p < 0.0021) with significant reductions in criteria that were totally missed.	Anesthesia apparatus checkout procedures are improved after intensive training sessions, although high rates of completion are not achieved. This performance deficit may have implications for the ability of physicians to detect anesthesia machine faults.
Larson et al. (2007)	A prospective study to determine whether there is a correlation between duration of anesthesia practice and the ability to detect anesthesia machine faults.	Retrospective review analysis Level 3	More anesthesia practice would increase the ability to detect anesthesia machine faults	87 anesthesia providers were observed performing anesthesia machine checkouts during a nationally attended anesthesia meeting held at a large academic medical center. There were 29 participants who had 0 –2 yrs. experience, 23 who had between 2 and 7 yrs. experience, and 35 participants who had more than 7 yrs. of experience.	Participants with 0 –2 yrs. experience detected a mean of 3.7 faults, participants with 2–7 yrs. experience detected a mean of 3.6 faults, and participants with more than 7 yrs. experience detected a mean of 2.3 faults (p < 0.001)	The prospective study demonstrated that anesthesia machine checkout continues to be a problem.

Mehta et al. (2013)	A retrospective study analysis of patient injuries related to anesthesia gas delivery equipment.	Retrospective review Analysis Level 3	Claims related to anesthesia gas delivery equipment were compared between time periods by chisquare test, Fisher exact test, and Mann–Whitney U test.	Patient injuries related to American Society of Anesthesiologists (ASA) closed claims database of 9,806 total claims	Anesthesia gas delivery claims decreased over the decades ($p <$ 0.001) to 1% of claims in the 2000s. Outcomes in claims from 1990 to 2011 ($n =$ 40) were less severe, with a greater proportion of awareness ($n =$ 9, 23%; $p = 0.003$) and pneumothorax ($n = 7$, 18%; $p =$ 0.047)	Human errors constituted an important factor in equipment failure.

Discussion

Larson and colleagues sought to identify anesthesia machine faults and to establish the correlation between duration of anesthesia practice and the ability of providers to identify machine faults.[12] The hypothesis was that more anesthesia practice experience would increase the ability of the provider to detect equipment failure. In addition, the study had several limitations that may affect its results. There was no instruction checklist to follow by the participants, and the participants were tested on an unfamiliar anesthesia machine. Despite the research limitation, the researchers asserted that continued education of anesthesia personnel on machine faults would improve fault detection.

Proper procedural checkout performance is necessary for detecting anesthesia machine faults. However, the research by Olympio and colleagues did not show that intensive review of checkout procedures would lead to a high completion rate.[13] The residents' understanding of the anesthesia workstation checkout recommendations was improved without major performance improvement. The pre-use checkout list was intended to limit intraoperative machine failure, and entry-level residents performed the anesthesia apparatus check-out almost at a rate equivalent to senior residents.

Blike and Biddle found that anesthesia machine faults detection continued to be a concern regardless of the anesthesia machine checklists used. The electronic checklists increased the detection of difficult tasks significantly compared to the FDA checklist, but overall faults detection was not improved with both anesthesia apparatus checklists. Blike and Biddle's research concluded that a modified electronic anesthesia machine checklist method yielded superior results in detecting difficult faults than the standard FDA checklist.[3] At the same time, practitioners failed to identify specific difficult faults even with the electronic checklist. Therefore, further research is needed to improve the procedure checklist for anesthesia machine check-out, to enhance provider's training, or design better equipment to avoid failure.

On the other hand, Henry concluded that educational training courses on detecting anesthesia machine fault improved participants' ability to detect anesthesia machine failure compared to participants who did not attend the educational course.[14] The anesthesia machine constituted one-third of the problems found. The most common problem was leakage and misconnection of the breathing system. Human errors were about one-quarter of the equipment problems. Based on the result of the study, equipment problems were a rare occurrence, and low severity and human errors played an important factor. The anesthesia machine was one-third of the equipment problems in Fasting and Gisvold's retrospective research.[5] The researchers concluded that human errors, due to insufficient pre-anesthesia machine check, were the main contributing factors in one-quarter of cases. Mehta and colleagues review analysis findings also confirmed human errors as one of the main factors to patient injuries in the ASA closed claims analysis.[15]

Purpose/PICO Clinical Questions/Objectives

PICO Question or Purpose

Population (P): Anesthesia providers

Intervention (I): Educational intervention

Comparison (C): None

Outcomes (O): Improve knowledge of prevention and management of intraoperative anesthesia machine failure

Primary DNP Project Goal

The anesthesia machine is an important medical equipment in the operating room that provides safe anesthesia delivery. The anesthesia apparatus is responsible for delivering oxygen and anesthetic gas to patients during surgery.[1] Despite being improved from a mechanical to a computerized electronic device, on rare occasions, the anesthesia machine tends to be subject to a system failure that can be detrimental to patient outcomes. Patient injury may result from the anesthesia delivery system malfunction if not properly managed. The anesthesia provider is responsible for the proper functioning of the anesthesia delivery system before using the device for surgery. Some studies found no improvement in anesthesiologists' detection of anesthesia machine faults despite using the United States Food and Drug Administration (FDA) anesthesia machine-recommended checklist.[11] However, the FDA apparatus checklist remains the standard for preoperative anesthesia machine check, and the practitioners' skills are crucial to managing the anesthesia delivery system safely.

Anesthesia machine failure incidences are found to be rare with low severity when occurred. Even though studies found practitioners failed to identify preset anesthesia machine faults, there are no other strategies to prevent machine failure other than preoperative equipment checks.[14] Other studies claimed improvements in anesthesia gas delivery equipment and provider adequate training in machine faults detection might increase patient safety.[2] Studies

have correlated anesthesia machine faults to human errors; therefore, anesthesia providers must be prepared at all times to prevent and manage anesthesia delivery system failure. There are a few suggested approaches to protect patients from injury related to anesthesia delivery system malfunction, such as pre-anesthesia equipment check applying national standards, appropriate evaluation and maintenance of equipment, pre-anesthesia check before clinical use, and rapid solutions in case of apparatus malfunction. Any unresolved issue with the anesthesia workstation may result in excessive gas delivery, inadequate depth of anesthesia, respiratory failure, cardiovascular complications, patient injury, and even death.[1] Human errors can be minimized through improved equipment designs that can alert providers of changes in patients' conditions to minimize patient injury in case of an anesthesia delivery system failure.

There have been several reports to the FDA of breathing circuit leaks with certain types of anesthesia machines.[6] Even though the facility recently replaced the old anesthesia machines with new different brands of anesthesia machines in the main operation room, other departments, such as obstetrics, continue to provide anesthesia with the old anesthesia machines. The goal of an educational intervention is to improve the knowledge of anesthesia providers on preventing and managing intraoperative anesthesia machine failure. The objective is to improve the knowledge of anesthesia practitioners on the anesthesia delivery system preoperative equipment check, detection, prevention of faults, and minimize human factors that may cause intraoperative anesthesia equipment malfunction.

Goals and Outcomes

The criteria to guide the goals of the quality improvement project and educational intervention were developed using the SMART acronym, which means the goal should be specific, measurable, achievable, realistic, and timely. An educational intervention on

preventing and managing intraoperative anesthesia machine failure that will improve the knowledge of anesthesia providers. A questionnaire analysis was used to evaluate the effectiveness of the educational intervention. The outcomes were measured by evaluating the anesthesia providers' knowledge improvement in anesthesia delivery system preoperative equipment check, detection, prevention, and management of anesthesia equipment malfunction. A software-generated survey and data analysis was created to generate the reports. Anesthesiologists, Certified Registered Nurse Anesthetists (CRNA), and anesthesia technicians will collaborate in the educational intervention to prevent and manage intraoperative anesthesia machine failure.

Anesthesia providers were educated on the prevention and management of intraoperative anesthesia machine failure. The quality improvement (QI) project on prevention and management of intraoperative anesthesia machine failure was completed within 2 months. Anesthesia practitioners had access to the pretest followed by a PowerPoint presentation on preventing and managing intraoperative anesthesia machine failure to optimize patient safety while delivering anesthesia during surgical procedures. Lastly, a posttest will be administered to assess the providers' improvement in knowledge.

Definition of Terms

Certified Registered Nurse Anesthetists (CRNAs)

Nurse anesthetists, also called certified registered nurse anesthetists (CRNAs), administer anesthesia to patients undergoing operations. They either administer a general anesthetic or use local anesthesia.[16]

Anesthesia

Anesthesia is the use of medicines to prevent pain during surgery and other procedures. These medicines are called anesthetics. They may be given by injection, inhalation, topical lotion, spray, eye drops, or skin patch. They cause you to have a loss of feeling or awareness.[17]

Anesthesia Apparatus

The modern anesthesia machine is a complex operating room instrument that incorporates a ventilator to optimize the delivery of inhaled anesthetics.[4]

Breathing Circuit

An anesthesia breathing circuit is a system of tubing, reservoir bag, and valves used to deliver a precise mixture of oxygen and anesthetic gases from the anesthesia machine to the patient and removal of carbon dioxide.[20]

METHODOLOGY

Setting and Participants

The quality improvement project occurred in an operating room setting in acute care hospital located in Broward Florida. About 20 to 25 anesthesia care providers practiced at this location delivering care to patients with diverse care needs and ethnic background. The employees at this location are comprised of anesthesiologists, CRNAs, registered nurses, anesthesia technicians, and surgical technicians to name a few.

Description of Approach and Project Procedures

The quality improvement project was implemented with the collaboration of anesthesia team experts after conducting a comprehensive and exhaustive literature review to develop the pretest, the voice-over PowerPoint presentation, and the posttest. Anesthesia providers at the facility volunteered to participate in the project. Participants were recruited virtually. Initially, a pretest questionnaire was provided to evaluate the knowledge of the anesthesia providers on

prevention, pre-anesthesia equipment check, detection, and management of anesthesia machine faults. After assessing the providers' knowledge, a 15-minute voice-over PowerPoint presentation was provided to anesthesia providers on anesthesia delivery system malfunction and management. After the educational intervention, a posttest survey was conducted to evaluate improvement in the providers' knowledge.

Protection of Human Subjects

Request to participate in the study was sent to anesthesia providers through virtual platform. This QI posed minimal risks to the participants. However, if the Institutional Review Board (IRB) decided there are potential risks to the participant associated with the project, informed consent was obtained to safeguard participants' privacy. The benefit of participating in the project is an improvement in the providers' knowledge to avoid and manage anesthesia machine failure. The participants may withdraw from the project anytime without consequences.

Data Collection

Demographic data collected was mainly gender, education, types of anesthesia providers and years of experience. The type of education was noted: Master or Doctorate degree. Participants were asked to provide number years of practice, and all the providers received the same educational intervention that comprised a pretest and a posttest.

Data Management and Analysis Plan

There was not any collection of direct identifiers of the participants. The pretest and posttest results were recorded and compared for analysis. Any data collected was stored electronically. The primary investigator had access to the data collected.

RESULTS OF QUALITY IMPROVEMENT PROJECT

Demographics

A total of 9 providers From ANESCO Anesthesia group at Broward Health System consented to participate in the study. The survey was completed by 8 of the 9 providers who consented to participate. Eight participants filled out the demographic data. All the participants were Certified Registered Nurse Anesthetists (CRNAs) (*n* = 8; 100%); the average age group was 44 years old. Female accounted for 62.5% of the providers (*n* = 5; 62.50%) and male 37.5% of the providers (*n* = 3; 37.5%). The participant ethnic groups varied from Caucasians (*n* = 3; 37.50%), Hispanics (*n* = 2; 25%), Asians (*n* = 1; 12.5%), and other non-identified ethnic participants (*n* = 2; 25%), African American (*n* = 0; 0%). The anesthesia providers years of experience in practice ranged from 0-2 years (*n* = 1; 12.5%), 3-5 years (*n* = 2, 25%), 6-10 years (*n* = 1; 12.5%), over 10 years of experience (*n*= 4; 50%). There were 4 CRNAs (*n* = 4, 50%) with Masters of Science in Nursing (MSN) and 4 CRNAs (*n* = 4, 50%) with Doctor in Nursing Practice (DNP).

Table 1. Demographics

Participants (n=8)	**Number**	**%**
Gender		
Male	3	37.50
Female	5	62.50
Race		
Caucasian	3	37.50
African American	0	0
Hispanic	2	25
Asian	1	12.5
Other	2	25

Position		
CRNA	8	100
Anesthesiologists	0	0
Level of education		
MSN	4	50
DNP	4	50
Years of experience		
0-2	1	12.50
3-5	2	25
6-10	1	12.50
Over 10	4	50

Pretest Knowledge

The pretest survey questions evaluated the Anesthesia providers' baseline knowledge of prevention and management of intraoperative anesthesia machine failure. Nine CRNAs consented to participate in the study, 8 CRNAs completed the demographic data, and 7 CRNAs continued on to complete the pretest. The pretest survey showed significant knowledge in prevention and management of anesthesia machine failure. Illustrated in Table 2, in general, the 7 participants who answered the pretest questions were well-informed in preventing anesthesia machine failure, identifying causes of anesthesia machine failure, and managing patients during an anesthesia workstation failure. Of the 7 (100%) participants who completed the 10 pretest questions, 8 of the 10 questions were answered correctly answered by the participants and 2 participants answered questions 1 and 3 questions incorrectly. Only 6 of the 7 participants answered question 5, which addressed the pre-anesthetic equipment check. The pretest survey

questions indicated that there were a deficit of 14.29% in anesthesia providers' knowledge in the area of both patient safety and checklist recommendation criteria related to anesthesia equipment failure.

Table 2. Pretest and Posttest Knowledge and Difference

Questions	Pretest (*n*= 7)	Posttest (*n*= 5)	Difference%
1. Faulty Anesthesia equipment components are rare and may NOT affect patient's safety. *TRUE* *FALSE****	6(85.71)	0(O) %) 5(100)	**+14.2%**
2. **Breathing circuit malfunction during a case may cause:** *Inadequate anesthetic gas delivery** *Birth defect* *Anxiety* *Infections*	7 (100%)	5 (100%)	NC
3. Anesthesia recommended checklist must: *Meet national standard* *Be specific to anesthesia machine in use* *Be approved by the ASA and AANA for the anesthesia machine in use* *All of the above**	6(85.71%)	5 (100%)	**+14.2%**
4. The two common causes of equipment failure are equipment's misuse and human factors. *TRUE ** *FALSE*	7 (100%)	5 (100%)	NC
5. Several studies associated failure to perform pre-anesthetic equipment checks with *Anesthesia workstation failure ** *Low cost anesthesia billing* *Improved patient outcome* *Improved patient safety*	6 (100%)	5 (100%)	NC
6. Human errors can be minimized by: *Designing equipment that minimizes human errors* *Designing equipment to minimize injury to patients*	7(100%)	5(100%)	NC

Designing equipment to include monitors and alarms to alert the provider of changes in the patient's condition resulting from equipment failure *All of the above**			
7. Anesthesia provider must ensure the proper functioning of the anesthesia delivery system: *Before use ** *That is the responsibility of the anesthesia technician* *During failure* *After use*	7 (100%)	5 (100%)	NC
8. Anesthesia providers use the anesthesia machine to safely deliver anesthetic agents to surgical patients. *TRUE ** *FALSE*	7 (100%)	5 (100)	NC
9. In case of a failed anesthesia machine during surgery the provider must: *Provide adequate ventilation to patients during surgery* *Access the patient airway* *Use a self-inflating mechanical ventilation device to maintain the patient airway* *Replace the anesthesia machine when unable to resolve the problem* *All of the above **	7(100%)	5 (100%)	NC
10. The pre-anesthesia equipment checkout procedure list does not always guarantee the proper functioning of device. *True ** *False*	7 (100%)	5 (100%)	NC
*** Correct Answer NC (No change)**			

Posttest Knowledge

After the participants completed the online pretest survey, followed by the PowerPoint educational module on prevention and management of intraoperative anesthesia machine failure, the participants completed a posttest survey to assess change in knowledge. The online posttest questions are identical to the questions that the participants completed in the pretest. Table-2 Illustrates there were 7 participants who completed the pretest, but only 5 participants (n = 5) completed the posttest. Knowledge in preventing anesthesia machine failure, identifying causes of anesthesia machine failure, and managing patients during an anesthesia workstation failure remained unchanged for all the participants; however, there were a 14.29% increase in knowledge in patient safety related to anesthesia equipment failure. Also, there was an increase of 14.29 % in knowledge in criteria for anesthesia recommended checklist. Overall, there was a 2.8% average improvement in knowledge.

Limitations

There were several limitations to the online survey. The sample size was small and significantly impact the outcome of the study. Initially, 9 providers consented to participate, only 8 participants completed the demographic data, 7 participants completed the pretest survey, and 1 participant of the 7 participants who completed the pretest survey questions failed to answer question number 1, 3 and question 5.

In comparison to the pretest questions, only 5 participants completed the posttest questions. Besides a small sample size, CRNAs providers were the only participants in the survey despites the email invitation was sent to all anesthesia ANESCO providers. Lastly, many of the emails listed for the ANESCO anesthesia providers at Broward Heath System were incorrect and contributed to a small number of providers participating in the study.

Discussion and Implications to Advance Practice

The project's goal is to improve the knowledge of anesthesia practitioners by educating the clinical practitioners on how to prevent and manage intraoperative anesthesia machine failure. There is a dearth of research on anesthesia machine failure; however, the few available studies concluded that many providers lack sufficient skills to detect preset anesthesia machine faults.[12] A review analysis of gas delivery equipment closed claims from the 1970s to the 2000s from the American Society of Anesthesiologists (ASA) database found that providers' errors such as misdiagnosed breathing circuit failure and inadequate alarms resulted in severe patient injuries.[15] Anesthesia management with equipment check protocol, checklist, and documentation has shown a significant decrease in risk of morbidity and mortality related to equipment failure.[11] The anesthesia providers must be skillful at preventing, detecting, and managing anesthesia delivery equipment failure.

The QI project will improve the practitioners' knowledge by reviewing and understanding the recommended standardized anesthesia procedural check approved by the American Association of Nurse Anesthesiology (AANA) and ASA for the anesthesia machine in use. The anesthesia providers will have the opportunity to review the specific instructions on detecting, preventing, and managing anesthesia machine failure. An educational intervention on anesthesia machine failure prevention and management will contribute to the safe delivery of anesthesia.

Conclusion

In summary, despite the rarity of anesthesia delivery system failure, anesthesia providers need to be adequately trained in addressing anesthesia equipment failure to avoid catastrophic patient outcomes. Many studies found human errors as a significant factor in equipment failure, such as the omission of pre-anesthesia apparatus checks. Intraoperative machine failure may be avoided using an approved checklist and adequate training for providers to manage anesthesia

equipment failure. Researchers suggested that the breathing circuit is the most common cause of equipment malfunction; therefore, the omission of pre-anesthesia equipment check may result in irreversible patient injuries such as cardiac and respiratory failure or light anesthesia if problems remain unresolved. Overall, anesthesia practitioners must possess adequate skills to prevent, identify, and manage intraoperative anesthesia equipment failure that may result in fatal outcomes.

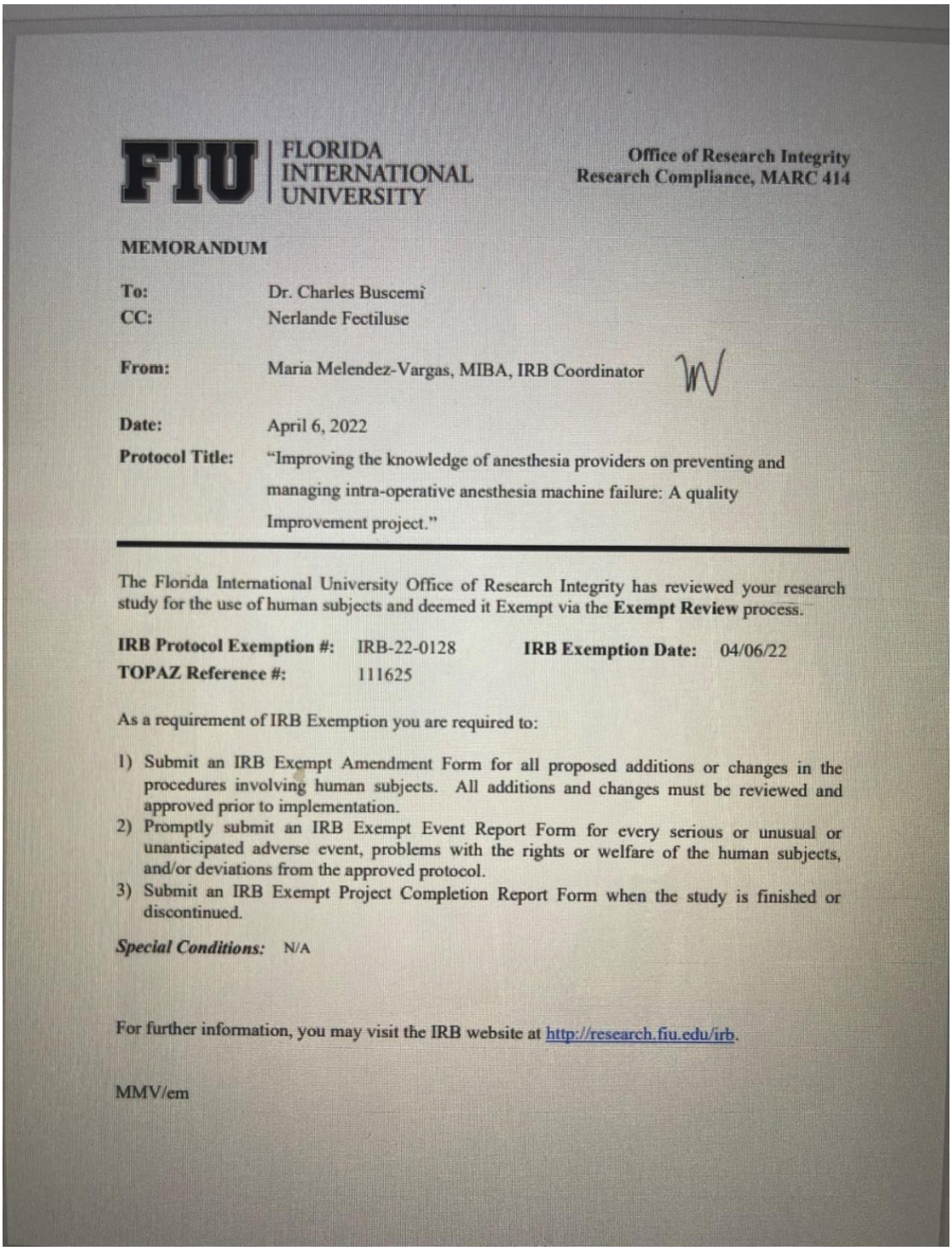
REFERENCES

1. Gurudatt C. The basic anaesthesia machine. *Indian J Anaesth*. 2013;57(5):438-445. doi:10.4103/0019-5049.120138
2. Goneppanavar U, Prabhu M. Anaesthesia machine: Checklist, hazards, scavenging. *Indian Journal of Anaesthesia*. 2013;57(5):533. doi:10.4103/0019-5049.120151
3. Blike G, Biddle C. Preanesthesia detection of equipment faults by anesthesia providers at an academic hospital: comparison of standard practice and a new electronic checklist. *AANA J*. 2000;68(6):497-505
4. Hill NE, Horn DB. Anesthesia Machine. PubMed. Published 2021. Accessed May 20, 2022. https://www.ncbi.nlm.nih.gov/books/NBK572060/
5. Fasting S, Gisvold S. Equipment problems during anaesthesia—are they a quality problem? *Br J Anaesth*. 2002;89(6):825-831. doi:10.1093/bja/aef276
6. Sen O, Bakan M, Umutoglu T, Aydın N, Toptas M, Akkoc I. Effects of pressure-controlled and volume-controlled ventilation on respiratory mechanics and systemic stress response during prone position. *SpringerPlus*. 2016;5(1). doi:10.1186/s40064-016-3435-3
7. Sullivan C. Awareness with recall: A systematic review. *AANA J*. 2016;84(4):283-288
8. Sigalovsky N. Awareness under general anesthesia. *AANA J*. 2003;71(5):373-379
9. Short TG, O'Regan A, Lew J, Oh TE. Critical incident reporting in an anaesthetic department quality assurance programme. *Anaesthesia*. 1993;48:3-7
10. Spittal MJ, Findlay GP, Spencer I. A prospective analysis of critical incidents attributable to anaesthesia. *Int J Qual Health* Care. 1995;7:363-71

11. Liu EH, Tan Y, Loh NH, Siau C. Potential rapid solutions to maintain ventilation in the event of anaesthesia machine failure with no access to the patient's airway. *Anaesth Intensive Care*. 2016;44(3):376-381. doi:10.1177/0310057X1604400311
12. Larson ER, Nuttall GA, Ogren BD, et al. A prospective study on anesthesia machine fault identification. *Anesth Analg*. 2007;104(1):154-156.
13. Olympio MA, Goldstein MM, Mathes DD. Instructional review improves performance of anesthesia apparatus checkout procedures. *Anesth Analg*. 1996;83(3):618-622.
14. Henry DW .Examination of the efficacy of education concerning a standardized anesthesia machine checkout procedure upon the machine fault detection ability of anesthetists. *AANA J.* 1989;57(6):500-504.
15. Mehta SP, Eisenkraft JB, Posner KL, Domino KB. Patient injuries from anesthesia gas delivery equipment: a closed claims update. *Anesthesiology.* 2013;119 (4):788-795.
16. NurseJournal. How to become a nurse anesthetist (CRNA). Published July 31, 2020. Accessed March 22, 2022. https://nursejournal.org/nurse-anesthetist/
17. Medline Plus. Anesthesia. Published 2018. Accessed February 12, 2022. https://medlineplus.gov/anesthesia.html
18. Ved S. Circle and Noncircle Systems. Access Medicine. Published 2014. Accessed January 01, 2022. https://accessanesthesiology.mhmedical.com/content.aspx?bookid=974§ionid=61586875

APPENDIX A

IRB LETTER



FIU | FLORIDA INTERNATIONAL UNIVERSITY

Office of Research Integrity
Research Compliance, MARC 414

MEMORANDUM

To: Dr. Charles Buscemi
CC: Nerlande Fectiluse

From: Maria Melendez-Vargas, MIBA, IRB Coordinator

Date: April 6, 2022

Protocol Title: "Improving the knowledge of anesthesia providers on preventing and managing intra-operative anesthesia machine failure: A quality Improvement project."

The Florida International University Office of Research Integrity has reviewed your research study for the use of human subjects and deemed it Exempt via the **Exempt Review** process.

IRB Protocol Exemption #: IRB-22-0128 **IRB Exemption Date:** 04/06/22
TOPAZ Reference #: 111625

As a requirement of IRB Exemption you are required to:

1) Submit an IRB Exempt Amendment Form for all proposed additions or changes in the procedures involving human subjects. All additions and changes must be reviewed and approved prior to implementation.
2) Promptly submit an IRB Exempt Event Report Form for every serious or unusual or unanticipated adverse event, problems with the rights or welfare of the human subjects, and/or deviations from the approved protocol.
3) Submit an IRB Exempt Project Completion Report Form when the study is finished or discontinued.

Special Conditions: N/A

For further information, you may visit the IRB website at http://research.fiu.edu/irb.

MMV/em

APPENDIX B

INFORMED CONSENT LETTER

CONSENT TO PARTICIPATE IN A QUALITY IMPROVEMENT PROJECT

"Improving the knowledge of anesthesia providers on preventing and managing intraoperative anesthesia machine failure: A Quality Improvement Project"

"

SUMMARY INFORMATION

Things you should know about this study:

- **Purpose:** Educational module to improve the knowledge of anesthesia providers on preventing and managing intraoperative anesthesia machine failure.
- **Procedures**: If you choose to participate, you will be asked to complete a pre-test, watch a voice PowerPoint and then a post-test
- **Duration:** This will take about a total of 20 minutes total.
- **Risks**: The main risk or discomfort from this research is minimal. There will be minimal risks involved with this project, as would be expected in any type of educational intervention, which may have included mild emotional stress or mild physical discomfort from sitting on a chair for an extended period of time, for instance.
- **Benefits:** The main benefit to you from this QI project is to improve the participant's knowledge in the prevention and management of intraoperative anesthesia machine failure.
- **Alternatives:** There are no known alternatives available to you other than not taking part in this study.
- **Participation:** Taking part in this QI project is voluntary.

Please carefully read the entire document before agreeing to participate.

PURPOSE OF THE PROJECT

You are being asked to be in a quality improvement project. The goal of this project is to improve the knowledge of anesthesia providers on preventing and managing intraoperative anesthesia machine failure.

DURATION OF THE PROJECT

Your participation will require about 20 minutes of your time. If you decide to participate you will be 1 of 10 participants.

PROCEDURES

If you agree to be in the project, we will ask you to do the following things:

1. Complete an online 10 question pre-test survey via Qualtrics, an online survey product for which the URL link is provided
2. Review the educational PowerPoint Module lasting 10 minutes via Qualtrics, an online survey product for which the URL link is provided
3. Complete the online 10 question post-test survey via Qualtrics, an online survey product for which the URL link is provided

RISKS AND/OR DISCOMFORTS

The main risk or discomfort from this project is minimal. There will be minimal risks involved with this project, as would be expected in any type of educational intervention, which may have included mild emotional stress or mild physical discomfort from sitting on a chair for an extended period of time, for instance.

BENEFITS

The following benefits may be associated with your participation in this project: An increased understanding on the prevention and management of intraoperative anesthesia machine failure.

The overall objective of the program is to increase patient safety and improve healthcare outcomes for our patients.

ALTERNATIVES

There are no known alternatives available to you other than not taking part in this project. However, if you would like to receive the educational material given to the participants in this project, it will be provided to you at no cost.

CONFIDENTIALITY

The records of this project will be kept private and will be protected to the fullest extent provided by law. If, in any sort of report, we might publish, we will not include any information that will make it possible to identify you as a participant. Records will be stored securely, and only the project team will have access to the records.

PARTICIPATION: Taking part in this project is voluntary.

COMPENSATION & COSTS

There is no cost or payment to you for receiving the health education and/or for participating in this project.

RIGHT TO DECLINE OR WITHDRAW

Your participation in this project is voluntary. You are free to participate in the project or withdraw your consent at any time during the project. Your withdrawal or lack of participation

will not affect any benefits to which you are otherwise entitled. The investigator reserves the right to remove you without your consent at such time that they feel it is in the best interest.

RESEARCHER CONTACT INFORMATION

If you have any questions about the purpose, procedures, or any other issues relating to this QI project, you may contact Nerlande Fectiluse at 305-303-4346 at nfect003@fiu.edu and Charles Buscemi at 305-348-4870 cbuscemi@fiu.edu

IRB CONTACT INFORMATION

If you would like to talk with someone about your rights pertaining to being a subject in this project or about ethical issues with this project, you may contact the FIU Office of Research Integrity by phone at 305-348-2494 or by email at ori@fiu.edu.

PARTICIPANT AGREEMENT

I have read the information in this consent form and agree to participate in this QI project. I have had a chance to ask any questions I have about this project, and they have been answered for me. By clicking on the "consent to participate" button below I am providing my informed consent.

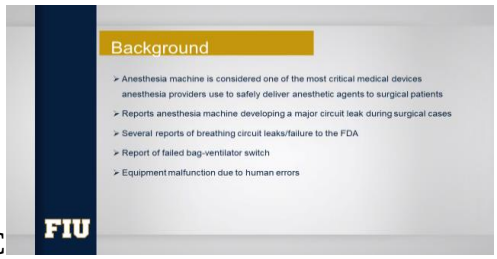
APPENDIX C

EDUCATIONAL MODULE

A

B

C



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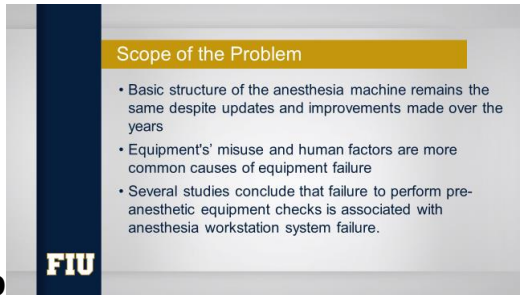

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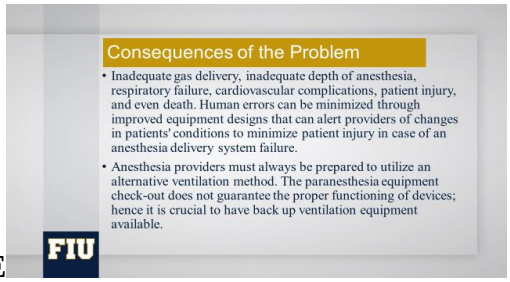

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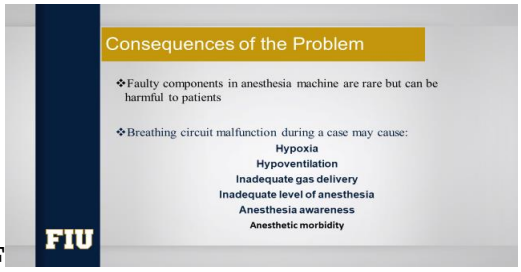

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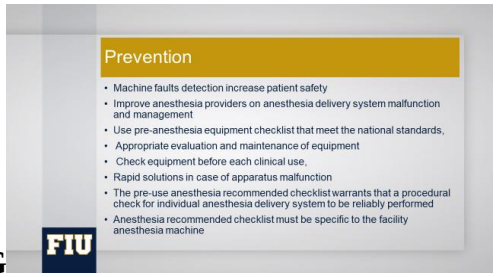

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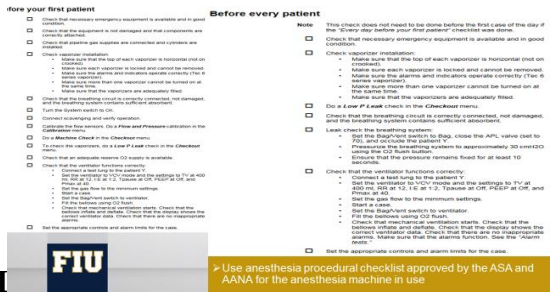

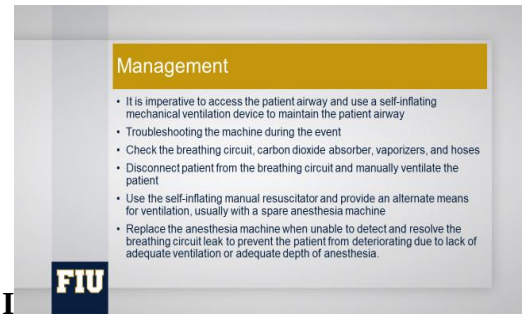

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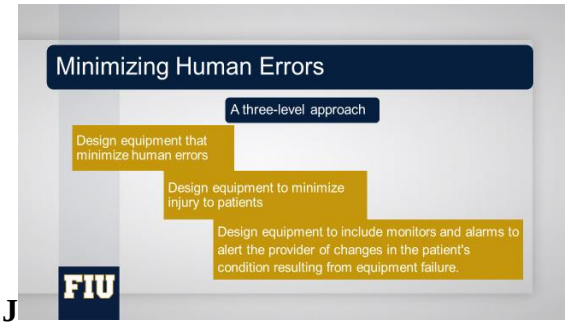

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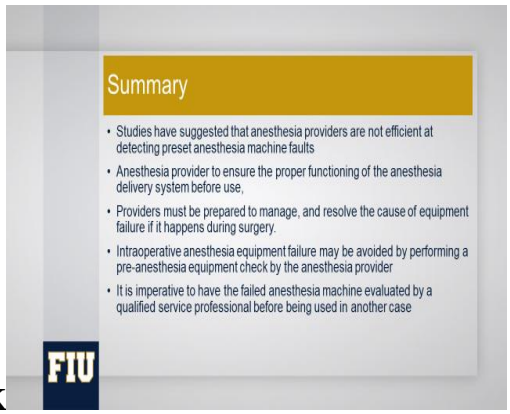

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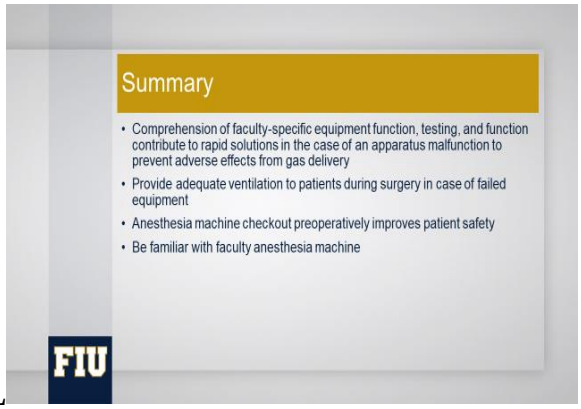

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References

1. Gurudatt C. The basic anaesthesia machine. Indian J Anaesth. 2013;57(5):438-445. doi:10.4103/0019-5049.120138
2. Goneppanavar U, Prabhu M. Anaesthesia machine: Checklist, hazards, scavenging. Indian Journal of Anaesthesia. 2013;57 (5):533. doi:10.4103/0019-5049.120151
3. Blike G, Biddle C. Preanesthesia detection of equipment faults by anesthesia providers at an academic hospital: comparison of standard practice and a new electronic checklist. AANA J. 2000;68(6):497-505
4. Gravenstein D, Wilkhu H, Liem EB, Tilman S, Lampotang S. Aestiva ventilation mode selector switch failures. Anesthesia & Analgesia. 2007;104(4):860-862. doi:10.1213/01.ane.0000256873.96114.48
5. Hill NE, Horn DB. Anesthesia Machine. PubMed. Published 2021. https://www.ncbi.nlm.nih.gov/books/NBK572060/
6. Fasting S, Gisvold S. Equipment problems during anaesthesia—are they a quality problem? British Journal of Anaesthesia. 2002;89(6):825-831. doi:10.1093/bja/aef276
7. Sen O, Bakan M, Umutoglu T, Aydin N, Toptas M, Akkoc I. Effects of pressure-controlled and volume-controlled ventilation on respiratory mechanics and systemic stress response during prone position. SpringerPlus. 2016;5(1). doi:10.1186/s40064-016-3435-3
8. Sullivan C. Awareness with recall: A systematic review. AANA J. 2016;84(4):283-288.
9. Signlovsky N. Awareness under general anesthesia. AANA J. 2003;71(5):373-379
10. Short TG, O'Regan A, Lew J, Oh TE. Critical incident reporting in an anaesthetic department quality assurance programme. Anaesthesia. 1993; 48: 3-7
11. Spittal MJ, Findlay GP, Spencer I. A prospective analysis of critical incidents attributable to anaesthesia. Int J Qual Health Care. 1995; 7: 363-71
12. Liu EH, Tan Y, Loh NH, Sim C. Potential rapid solutions to maintain ventilation in the event of anaesthesia machine failure with no access to the patient's airway. Anaesth Intensive Care. 2016;44(3):376-381. doi:10.1177/0310057X1604400311
13. Larson ER, Nuttall GA, Ogren BD, et al. A Prospective Study on Anesthesia Machine Fault Identification. Anesthesia & Analgesia. 2007;104(1):154-156.
14. Olympio MA, Goldstein MM, Mathes DD. Instructional Review Improves Performance of Anesthesia Apparatus Checkout Procedures. Anesthesia & Analgesia. 1996;83(3):618-622.
15. 15 Henry DW. Examination of the efficacy of education concerning a standardized anesthesia machine checkout procedure upon the machine fault detection ability of anesthetists. AANA J. 1989;57(6):500-504.
16. Mehta SP, Eisenkraft JB, Posner KL, Domino KB. Patient Injuries from Anesthesia Gas Delivery Equipment:A Closed Claims Update. Anesthesiology: The Journal of the American Society of Anesthesiologists. 2013;119 (4):788-795.
17. How To Become A Nurse Anesthetist (CRNA) | NurseJournal.org. NurseJournal. Published July 31, 2020. https://nursejournal.org/nurse-anesthetist/
18. Anesthesia. Medlineplus.gov. Published 2018. https://medlineplus.gov/anesthesia.html
19. Ved S. Circle and Noncircle Systems. Access Medicine. Published 2014. Accessed January 1, 2022. https://accessanesthesiology.mhmedical.com/content.aspx?bookid=974&sionid=61586875
20. Avance - Frank's Hospital Workshop. http://frankshospitalworkshop.com/equipment/documents/anaesthesia/user_manuals/Datex-Ohmeda%20Avance%20-%20User%20Reference%20Manual.pdf.

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APPENDIX D

PRETEST AND POSTTEST QUESTIONNAIRE

Pretest and Posttest Questionnaire:

Prevention and Management of Intraoperative Anesthesia Machine Failure

INTRODUCTION

The primary aim of this QI project is to improve the knowledge of anesthesia providers on preventing and managing intraoperative anesthesia machine failure to increase patient safety.

Please answer the question below to the best of your ability. The questions are either in multiple choice or true/false format and are meant to measure knowledge and perceptions on preventing and managing intraoperative anesthesia machine failure.

PERSONAL INFORMATION

1. **Gender:** Male Female Other_____
2. **Age:** _____
3. **Ethnicity:** Hispanic Caucasian African American Asian

   Other_____
4. **Position/Title:** _____
5. **Level of Education:** Associates Bachelors Masters

   Other _____
6. How many years have you been an anesthesia provide?

Over 10 5-10 years 2-5 years 1-2 years

QUESTIONNAIRE

1. **Faulty Anesthesia equipment components are rare and may have not affect patient's safety.**
    a. True
    b. False
2. **Breathing circuit malfunction during a case may cause:**
    a. Inadequate anesthetic gas delivery
    b. Birth defect
    c. Anxiety
    d. Infections
3. **Anesthesia recommended checklist must be**
    a. Meet national standard
    b. Specific to anesthesia machine in use
    c. Approved by the ASA and AANA for the anesthesia machine in use
    d. All the above
4. **The two common causes of equipment failure are equipment's misuse and human factors.**
    a. True
    b. False
5. **Several studies associated failure to perform pre-anesthetic equipment checks with**
    a. Anesthesia workstation failure

b. Improved patient outcome

c. Improved patient safety

d. Low cost anesthesia billing

6. **Human error can be minimized by :**

a. Design equipment that minimize human errors

b. Design equipment to minimize injury to patients

c. Design equipment to include monitors and alarms to alert the provider of changes in the patient's condition resulting from equipment failure

d. All of the Above

7. **Anesthesia provider must ensure the proper functioning of the anesthesia delivery system**

a. Before use

b. After use

c. During failure

d. That is the responsibility of the anesthesia technician

8. **Anesthesia providers use the anesthesia machine to safely deliver anesthetic agents to surgical patients**

a. True

b. False

9. **In case of a failed anesthesia machine during surgery the provider must:**

a. Provide adequate ventilation to patients during surgery

b. Access the patient airway

c. Use a self-inflating mechanical ventilation device to maintain the patient airway

d. Replace the anesthesia machine when unable to resolve the problem

e. All of the above

10. The pre-anesthesia equipment checkout procedure list does not guarantee the proper functioning of device

a. True

b. False